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HISTORICAL NOTICE OF JOHN NELSON STOCKWELL OF CLEVELAND.

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In the death of Professor John Nelson Stockwell, of Cleveland, Ohio, May 18, 1920, America has lost one of her foremost philosophers and the dean of her astronomers. Professor Stockwell was the contemporary of Gould, Hall, Newcomb and Hill and outlived them all by a considerable period of years. Fortunately his health enabled him to be active to the very end; so that as in the case of the elder Herschel, some of his notable advances were made at a great age. Accordingly, his devotion to Science extends from 1850 to 1920—fully seventy years!

Dr. Stockwell was born at Northampton, Mass., April 10, 1832, and thus was in the 89th year of his age. Up to within a week of his death he was in the best of health and spirits, and working away with his usual zeal and industry on his many unfinished researches, which included a revision of the theory of the Tides and certain problems of the Moon's Motion.

As Dr. Stockwell has set an extraordinary example of devotion to Truth, over the full three score and ten years usually allotted to the life of man, an account of his labors will be valuable to the country; and thus we shall trace his career briefly, and endeavor to outline the researches which chiefly engaged his attention.

(i) *Ancestry, childhood, and early education.*

In the days of Dr. Stockwell's childhood, the whole of Ohio, so recently carved out of the great Northwest Territory, was in a very primitive condition. In America as a whole education was not well developed, except in a few centers east of the Allegheny Mountains. Accordingly, although the child who was to be the future astronomer, was born at West Farms, Northampton, Mass., April 10, 1832, his parents moved to Ohio in the autumn of 1833, and thus nearly the whole of his life was spent in Ohio, in the region of Cleveland.

The Stockwell family had come from England about the beginning

of the 18th century, and settled in the colony of Connecticut. Authentic records show that William Stockwell No. 1 was born at Thompson, Connecticut, in 1744, and resided there till 1786. William Stockwell No. 2 was also born there in 1773, but in 1786 moved with his father to Northampton, Massachusetts, where the father of Dr. Stockwell, William Stockwell No. 3, was born August 19, 1796.

Dr. Stockwell's mother's maiden name was Clarissa Whittemore, and she was born at Brookfield, Mass., Dec. 7, 1800. Her uncle, Amos Whittemore, had invented the ingenious machine for carding wool and cotton, which afterwards proved so valuable in the manufacture of cloth.

Dr. Stockwell's parents, William Stockwell No. 3, and Clarissa Whittemore, were married May 19, 1826, and resided on West Farms, Northampton, Mass., for seven years. Meanwhile they had five children, four of whom lived to adult age,—the youngest being John Nelson Stockwell, the subject of this sketch.

It is of record that at birth this future astronomer was so frail that his life was despaired of; yet by the devoted care of his mother he survived, and finally attained the greatest age of any American astronomer up to the present time. When the parents reached Ohio in the autumn of 1833, they spent the first winter at the hamlet of Campbellsport, in Portage County. At the age of three years the future astronomer first ran away with his older brothers to school; but, proving stubborn in some trivial matter of discipline, had to be shut up in a dark closet to conquer a childish obstinacy.

The family moved several times, from one township to another, prior to 1840, at which time there were eight children. And as the means of support were slender, young Stockwell at the age of eight was taken to live with an elderly aunt and uncle, Oliver Edgerton, only recently married. They resided near Cleveland, in Brecksville Township, Cuyahoga County. With this uncle lived also his own uncle, nearly eighty years of age. There were no other children in this family, and it was intended that the boy should stay in his new home only a short time; but years passed by, and he became so attached to his foster parents that he did not care to leave them.

At fourteen the boy had become robust, and as his own parents now needed him on their farm, they applied for his return; but as the uncle and aunt wished to retain him, an indenture was at once made in writing, by which he was to remain with them till the age of twenty-one. He was to do farm work nine months, spring, summer and autumn, and attend district school in the three winter months of the year.

Although young Stockwell had attended school at an early age, his interest in books was slight till he reached the age of twelve. Finally "Webster's Elementary Spelling Book," and "McGuffey's First Reader" awakened an interest in the child's mind; and soon the Mexican War broke out, and a war with England seemed imminent over the

Oregon Boundary Question. He was thus awakened from his intellectual slumber, to become a great reader.

With his foster parents he attended the Presbyterian Church, in the neighboring town, and after the first service, at ten o'clock A. M., he would go to Mr. Theodore Breck's office to spend an hour in his library, before the second service began. This library was the best in the town, and contained Headley's "Washington and his Generals", and accounts by the same writer of Napoleon's chief military operations. The works thus accidentally found awakened a wider interest, including history and science.

One of the neighbors subscribed to a weekly "Dollar Newspaper," published in Philadelphia, which contained a series of Arithmetical Problems, some of them of extreme interest. An old Arithmetic also fell into the boy's hands, and contributed to the development of his mathematical taste. The three winter months of school, in the years 1847-9, were intensely devoted to Arithmetic, Grammar, and Geography; and thus at seventeen the boy had mastered the chief studies in the common schools of Ohio.

Throughout this period young Stockwell continued to solve the problems of the "Dollar Newspaper", one of which was: "Required the number of acres in a square field enclosed by a rail fence having sixteen rails to the rod, in order that the number of acres in the field should be equal to the number of rails in the fence." The boy not only solved the problem, but obtained a general rule for similar problems; and when he proposed it to Mr. Leonard Case, subsequently renowned as the founder of the Case School of Applied Science, Cleveland, this gentlemen had to employ higher mathematics for its solution.

In a summary of the expense of his common school education, written down in his advanced years, Professor Stockwell gave the following items:

Adam's Arithmetic (second hand)	$0.50
Webster's Elementary Spelling	0.10
McGuffey's Fourth Reader	0.75
Porter's Rhetorical Reader	0.75
Hale's History of the United States	0.63
Kikham's Grammar	0.70
Mitchell's School Geography and Atlas	1.00
Total	$4.43

(ii) *Early studies in Algebra and Astronomy.*

The account of his introduction to Science, written by Dr. Stockwell himself, is of so much interest that we quote it at length:

"In the spring of 1849 I commenced the study of Algebra. The public schools provided no instruction in that science, and I had no means for pursuing it elsewhere. I was, therefore, obliged to get along without assistance or abandon the study. The difficulties which I first encountered, however, gradually disappeared, and I was surprised at the simplicity and elegance with which arithmetical problems could

be handled by means of algebra. I afterward made the discovery that no teacher was necessary.

"I have often been asked how I happened to take an interest in astronomy, and at what age that interest manifested itself. It is easy to answer both of these questions now, although at one time it was a little difficult to answer the latter with certainty. Two circumstances, however, which I well remember enable me to determine the date. My interest was awakened to the subject of astronomy by a total eclipse of the moon which occurred early in the evening, about the beginning of winter. I have already mentioned the fact that I lived with my uncle, and that he lived with his uncle, who was nearly eighty years of age. We were all somewhat frightened at the occurrence, and the old gentleman asked me, with some earnestness, if I thought that I would ever be able to foretell when such an event would occur again. The idea of foretelling such an event was entirely new to me. I had never heard of such a science as Astronomy, and I could only reply to the old gentleman by saying that I didn't know but that I would try. From that time on I was a careful student of all the old Almanacs that I could get possession of, and I picked up a good many items of interest in Astronomy.

"To fix the date of that event, after the lapse of more than forty years, was a matter of some difficulty; but several circumstances have led to its determination. The first of these circumstances was the fact that I was then living in Brecksville. Now, I first went to Brecksville in May, 1840, and remained there nearly a year, when I returned to Ravenna and stayed at home nearly a year, but returned to Brecksville again in 1842. The eclipse could not have happened earlier than 1842. The old gentleman who figured in connection with the eclipse died in the year 1848, so that the eclipse must have taken place between the years 1842 and 1848. Again, the eclipse occurred early in the evening, about the beginning of winter, as I well remember, it being then quite cold weather. Now, I find, by calculation, that the only eclipse of the moon which occurred under that combination of circumstances between the years of 1842 and 1848 was that of 1844, November 24th, in which the moon was totally eclipsed at twenty minutes past six o'clock in the evening, at which time I was twelve years, seven months and fourteen days old.

"Antenatal influences may have had something to do in the production of my astronomical tastes. My mother has often told me that the people were greatly excited over the prediction that Biela's Comet would come in collision with the earth in 1832, and destroy the world. She must have been affected by the popular excitement.

"I found the study of Algebra so interesting that I devoted every leisure moment to its consideration, and in the period of about eight months I had solved nearly every problem in Day's Algebra, which was then used in the principal colleges of this country. In the autumn

of 1849 I procured a little book on practical geometry and during the winter worked all the problems it contained and in the spring of 1850 I entered upon the study of general Geometry. In fact, I became so absorbed in study that the labors of the farm became rather irksome, and I sometimes suspect that the growing crops suffered detriment for the benefit of science. There certainly seemed to be a degree of incompatibility between my natural tastes and my occupation, and this incompatibility soon led to a modification of the conditions that were so satisfactory at the age of fourteen."

(iii) *Young Stockwell becomes an Astronomer.*

Dr. Stockwell's own story of his development in Astronomy is so instructive, that we again quote from his condensed narrative.

"It was about that time that the wonderful discovery of Neptune took the scientific world by surprise, and the fame which rewarded the theoretical discoverer of that planet served as a stimulus to continued exertion. In 1850, while attending the College Commencement at Hudson, in July, I found Olmstead's Astronomy with Mason's Supplement, which I purchased and which I afterwards read with a great deal of interest. I also obtained the writing of Dr. Thomas Dick who was a very charming, popular writer on scientific subjects. His works called "Celestial Scenery", "Sidereal Heavens" and "The Practical Astronomer" afforded a vast amount of general information on the subject of Astronomy. In a general way they stated the facts and laws that had been discovered by the promoters of the science, but they failed to inform the reader how the discoveries had been effected. These works, therefore, stimulated rather than satisfied my desire for astronomical knowledge. But they contained occasional references that were of great service in directing my attention to proper sources of information. For instance, Olmstead, in his preliminary observations, says, 'Near the beginning of the eighteenth century Sir Isaac Newton discovered, in the law of universal gravitation, the great principle that governs the celestial motions, and recently Laplace has more fully completed what Newton began, having followed out all the consequences of the law of universal gravitation in his great work the "Mécanique Céleste".' And later in his work, when speaking of the consequences of the law of gravitation he says, 'A few of them are all that can be exhibited in a work like the present; their full development must be sought for in such great works as the Mécanique Céleste of Laplace'. There were also numerous allusions to Laplace in the works of Dr. Dick, and the thought occurred to me that that was *the* book of all books that I most needed. I, therefore, inquired at the book stores in Cleveland and Hudson for the Mécanique Céleste of Laplace, but no one had it or knew anything about it. A year later, however, the Messrs. J. B. Cobb & Company thought they could get it for me, although they knew nothing in regard to the price of the work. However, as books were then comparatively cheap, I ventured to order it,

not supposing that the cost of it would amount to more than five or ten dollars at the outside.

"It was not till the spring of 1852, when I was twenty years of age, that the work of Laplace reached Cleveland; and, instead of being a single book of moderate dimensions, it consisted of four large quarto volumes containing, in the aggregate, 3770 pages of the most difficult mathematical work that can well be imagined. The cost, also, was seemingly enormous, for instead of being only five or ten dollars, it amounted to forty dollars, and I felt for once that I had an elephant on my hands, aside from half a summer's work to get the money to pay for it.

"I had, however, in the meantime, procured such books on the higher mathematics as the country afforded, and had become somewhat familiar with the language of the *Calculus*, which confronts us on nearly every page of that immortal work. For this reason I had a feeling of friendship for the work, notwithstanding its formidable dimensions and the austerity of its interior. It was, however, a number of years before I ceased to be awestruck in its presence, feeling that no one but its author could properly interrogate its pages or fully comprehend its mysteries.

"During the years 1849-51 I devoted my little leisure to the study of astronomy, geometry, trigonometry and the higher mathematics, and had made so much proficiency in those sciences that in 1852 I resolved to make myself famous by the publication of a 'Western Reserve Almanac for the Year of Our Lord 1853.' The computation of that almanac caused me a vast amount of labor by any method that I was then able to devise, but it was successfully accomplished, and the Messrs. J. B. Cobb & Company undertook its publication. But by a singular fatality my name was accidentally omitted from the title page and the author's incognito never exploded. However, it was a draw game between the author and the publisher, and their amicable relations were not in the least disturbed by the transaction.

"About that period Prof. Elias Loomis published a little book entitled 'The Recent Progress of Astronomy', in which he gave an interesting account of the discovery of the planet Neptune, by means of mathematical calculations, based on the observed disturbances in the motion of the planet Uranus, as well as an account of the discovery of several new planets between the orbits of Mars and Jupiter, which are called asteroids. These accounts indicated wonderful activity in the scientific and astronomical world, and served to stimulate my own efforts in the same direction. But in addition to the actual astronomical discoveries announced in the book, the statement was made that the publication of a Journal whose pages were devoted exclusively to astronomical investigations had recently been undertaken in this country and that it would undoubtedly be productive of great benefit to the sciences.

"I immediately subscribed for the Journal and it was afterwards my good fortune to become acquainted with its Editor, Dr. B. A. Gould, of Cambridge, Massachusetts. This acquaintance was made early in the year 1854 and has continued uninterruptedly till the present time, and I attribute much of the success of my labors in astronomical work to the disinterested and friendly interest he took in my welfare."

(iv) *Stockwell's early association with Dr. Gould,* 1854-1865.

"In 1854 Dr. Gould, in replying to an inquiry, offered me a situation as computer in the Longitude Department of the United States Coast Survey, which was then under his direction, at a salary of $400.00. This I accepted and in August of that year I left home for Cambridge, Massachusetts. It was the first time that I had ever been away from home for more than a week at a time, and the conditions under which I found myself, although agreeable in every respect, were so different from those to which I had been accustomed, that I naturally became a little homesick, and after an absence of eight months, I returned to Brecksville. I had, however, during my absence, collected quite a number of valuable scientific books which were afterwards of great service in the pursuit of mathematical astronomy.

"It was not my purpose, however, to abandon the study of astronomy, but inasmuch as my uncle and aunt desired me to remain with them, as they were getting somewhat advanced in years, I decided to do so, and devote such part of the time, as could be spared from necessary labor on the farm, to study. There was also another attraction which no doubt had a great deal of influence in shaping my course at that time, and that was an estimable young lady, Miss Sarah Healy, who had lived in the family during about ten years, and to whom my uncle and aunt were greatly attached. Towards the close of the year 1855 (December 6) we were married, and we continued to reside at the same place until after the breaking out of the War of the Rebellion in 1861.

"During that period I had given a good deal of time to the study of astronomy, and had mastered the methods of computation of the orbits of planets and comets, and had actually computed the orbits of two comets which appeared in the year 1853. I also find that I computed the orbit, perturbations and ephemeris of *Virginia,* the fiftieth asteroid, for the opposition of 1859. These investigations were all published in the *Astronomical Journal* before the end of the year 1858. In May, 1860, I computed and published another ephemeris for the opposition of *Virginia,* for the opposition in that year, and in July of the same year I published a new method of solving a set of symmetrical equations having indeterminate coefficients.

"Aside from these investigations I had commenced a very extensive and elaborate computation of the secular variations of the planetary orbits arising from their mutual attractions on each other, but this investigation was interrupted by the war and was not completd until

1872 when it was published in the Smithsonian Contributions to Knowledge.

"On the breaking out of the war in 1861, Lieutenant Maury, who was then Superintendent of the United States Naval Observatory at Washington, deserted his post and fled into the Confederacy, and Lieutenant J. M. Gillis was then appointed in his place. The new Superintendent found the affairs of the Observatory in a state of great disorder and confusion. Thousands of observations had been made and allowed to accumulate without being reduced and published, and he immediately took measures to bring forward all arrearages of that character. My friend, Dr. Gould, was appointed to superintend the required reductions and he at once offered me a position as computer, which I accepted."

(v) *Stockwell befriended by Mr. Leonard Case,* 1865-1888, *who encouraged him to finish the researches on the Secular Variations of the eight principal planets,* 1872, *and on the Motion of the Moon,* 1875.

"I commenced work on those reductions in the autumn of 1861 and they were finished in the autumn of 1864, but during the war the United States Sanitary Commission had collected a vast quantity of valuable statistics in regard to the sanitary conditions affecting the Union Armies, and the discussion of these statistics was intrusted to Dr. Gould. I, therefore, continued in the employ of Dr. Gould during the continuance of that work, which was completed towards the end of 1867. During the winter of 1864-5 I was in Washington, engaged on the Sanitary Commission work, and while there I had occasion to order some books from Europe on the Theory of Probabilities. There was a good deal of delay in getting these books, and I mentioned the fact to the Messrs. J. B. Cobb & Company, on my return from Washington. It was to this trivial circumstance that my acquaintance with Leonard Case was due, for Mr. Cobb afterward, in a casual conversation with Mr. Case, mentioned the non-arrival of the books which I had ordered from Europe. Now, it so happened that Mr. Case had the very books that I wanted, in his library; and he at once informed me by letter, dated 1865, June 5th, of that fact, and very kindly placed them at my service. But in the meantime the books I had ordered had reached me, so that there was no occasion for the acceptance of his kind offer. In a subsequent letter (dated June 24th) he stated that he sometimes took long horseback rides, and that if I would tell how to find me, he would 'drop in' and see me when occasion offered. I very willingly gave him the desired information and, in due course of time, he came to see me. We had a very pleasant interview, and he manifested great interest in the mathematical and astronomical books of my library. On leaving he very cordially invited me to call on him whenever I came to town. But circumstances very soon made it necessary for me to move

with my family to Cambridge, Massachusetts, and I saw nothing more of him until after more than two years from the time of our first interview.

"My work for the Sanitary Commission was completed about the first of December, 1867, and as nothing of special interest offered in the way of business in Cambridge, I at once returned to Ohio. But in the meantime I had kept up some correspondence with Mr. Case, and, on my arrival in Cleveland, he met me at the depot with a carriage and took us all to his home on Rockwell Street, and towards night we took our departure for our old home in Brecksville.

"It was my intention, on reaching home, to resume and complete the work on the secular variations of the orbits of the eight principal planets, which I had commenced before the war.

"My acquaintance with Mr. Case was most fortunate, and his friendship was cordial and continuous during the remainder of his life. From him I received the material encouragement which has enabled me to devote the greater part of my time during the past twenty years to scientific pursuits. It was he who encouraged me to undertake a complete discussion of the mathematical theory of the moon's motion, the subject on which I was engaged at the time of his death, and which I have continued at intervals since. But the continuity of effort was then broken, and I have since been obliged to confine my attention to some specific problem in relation to the subject, rather than to a general advance all along the line.

"The results of my investigations during the past ten years are mostly published in the *Astronomical Journal*, and among these papers I find the following:

1. Observations of the Solar Eclipse of August, 1886.
2. Inequalities of the Moon's Motion produced by the oblateness of the Earth.
3. Inequalities of the Moon's Motion produced by the Planets.
4. Long period inequalities of the Moon's Motion produced by the action of Venus.
5. Secular and long period inequalities of the Moon's Motion, containing a discussion of several ancient eclipses.
6. The Mean and Secular Motion of the Moon's perigee.
7. On the Rectification of Chronology by Ancient Eclipses.

"During the past four years my time has been mostly devoted to the discussion of Ancient Eclipses for Chronological Purposes. The earliest of these bears the date B. C. 3784, October 20, and was visible throughout India. The next in interest and importance took place in B. C. 2136, October 10, and was visible in China. This is the only eclipse which was visible in China during the twenty-second century B. C., that occurred on the day of the Autumnal Equinox, and is probably the one for which the Astronomers Ho and Hi were put to death for having failed to predict. I have computed

nearly one hundred ancient eclipses, only a few of which have been published, but the list is too long to be given here."

(vi) *List of Dr. Stockwell's principal researches to the year* 1905.

In a later note on his researches, Dr. Stockwell adds:

"The preceding sketch was prepared nearly twenty years ago and since that time I have done a good deal of laborious work in preparing the papers mentioned in the following list and have very nearly completed a work on "Celestial Mechanics." Aside from chronological investigations, I have made extensive calculations for a work of a popular character which is in course of preparation and to which I have given the title of "The Skies of Past and Future Ages." This work will contain the places of the principal fixed stars during a period of 32,000 years, commencing 16,000 years ago and continued to 16,000 years in the future. It will also contain the place of the pole and of the equinox for the same period.

"I have also made other calculations which show the angular distances of the principal fixed stars from each other. These calculations have cost a good deal of labor, and the number of distances already computed amount to about 2,500. These distances, when compared with the distances which are found in future ages, will show the changes that are taking place among the stars arising from the motions of the stars themselves and independent of the motion of the earth."

(a) *Titles of Papers published in Gould's Astronomical Journal.*

1. Orbit of the third Comet of 1853, Vol. V. 10 P., 1856.
2. Orbit of the second Comet of 1853, Vol. V. 2 P., 1857.
3. Ephemeris of *Virginia* (50), Vol. VI. 2 P., 1860.
4. Resolution of symmetrical Equations with indeterminate coefficients. Vol. VI. 9 P., 1860.
5. Inequalities of Moon's Motion produced by Oblateness of the Earth. Vol. VII. 31 P., Nos. 145-149, 1886.
6. Inequalities of Moon's Motion produced by Action of Planets, Vol. VII. 16 P., 158-9, 1887.
7. Inequalities of Moon's Motion produced by Action of Venus, Vol. VII. 11 P., 163, 1887.
8. Secular and long period inequalities in the Moon's Motion, Vol. IX. 29 P., 220-1, 1890.
9. Supplement to above, Vol. IX. 4 P., 225.
10. On the Theory of the Moon's Motion, Vol. IX. 6 P., 231, 1890.
11. On the Mean and Secular Motion of Moon's perigee, Vol. IX. 3 P., 235, 1891.
12. Rectification of Chronology by means of Ancient Eclipses, Vol. X. 10 P., 240, 1891.
13. The True date of the Battle of Pydna, Vol. XI. 1 P., 241, 1891.
14. Chronology and Eclipses. Vol. XI. 4 P., 244, 1891.
15. Eclipses and Chronology, Vol. XI. 5 P., 248, 1891.
16. Supplement to Recent Contributions to Chronology and Eclipses, Vol. XII. 12 P., 280, 1892.
17. Chronology and Eclipses. Vol. XIII. 3 P., 298, 1893.
18. Theoretical Inequalities of long period in the motions of the Earth, Mars, Jupiter and the Moon. Vol. XIII. 13 P., 304, 1893.
19. The Law of Recurrence of Eclipses on the same day of the Tropical Year. Vol. XV. 6 P., 346, 1895.

20. A New Method of Finding the Place of a Ship at Sea, Vol. XIII. 7 P., 306, 1893.
21. Eclipses and Chronology. Vol. XVI. 8 P., 372, 1896.
22. Occultation of Star B. A. C. 1746, Vol. XVI. 1 P., No. 376, 1896.
23. Eclipses and Chronology: A Reply to Mr. Lynn. Vol. XVI. 2 P., 380. 1896.
24. An explanation of the Errors in the Theory and Tables of the Moon's Motion. Vol. XVII. 7 P., 402, 1897.
25. Note on the Precession of the Equinoxes. Vol. XVIII, 2 P., 415, 1897.
26. Eclipse-Cycles. Vol. XXI. 13 P., 504, 1901.
27. Theory of the mutual perturbations of planets moving at the same mean distance and its bearing on the constitution of Saturn's Rings and the cosmogony of Laplace. Vol. XXIV. 9 P., 557, 1904.

(b) *Titles of Papers published in the "Observatory," London.*

1. The Eclipse of Archilochus. No. 205, 1 P., 1893.
2. Chronology and Eclipses. No. 223, 2 P., 1895.
3. Eclipses and Chronology. No. 226, 2 P., 1895.
4. Eclipses and Chronology. No. 236, 1896.
5. Eclipses and Chronology. No. 237, 2 P., 1896.
6. Eclipses and Chronology. No. 240, 1 P., 1896.
7. Eclipses and Chronology: A Reply to Mr. Lynn. No. 244, 1 P., 1896.

(c) *Titles of Papers published in the American Journal of Science.*

1. Secular variation of Earth's Orbit. 1868, Vol. 26, 3 P.
2. Secular Inequalities of Moon's Motion due to oblateness of Earth. 1879, Vol. XVIII, 3 P.
3. Secular Inequalities of Moon's Motion due to oblateness of Earth. 1880, Vol. XIX, 6 P.
4. Lunar Theory. 1880, Vol. XX, 9 P.
5. On Hill's Supplement to Delaunay. 1885, Vol. XXIX, 3 P.

(d) *In Popular Astronomy.*

1. On the Eclipse predicted by Thales. 1901, Vol. IX, 13 P.

The above list is incomplete for the last fifteen years of Dr. Stockwell's life,—and I have not been able to supply the data—but his contributions will be found mainly in the *Astronomical Journal* and in *Science,* and therefore are accessible in our chief libraries.

(vii) *General Remarks on Dr. Stockwell's Astronomical Researches.*

As the above list of Dr. Stockwell's Papers is moderately complete, we shall not here go into details of his extensive and varied researches, but will confine our attention chiefly to the two memoirs which are best known and probably the most important of his investigations.

(A) *Memoir on the Secular Variation of the Elements of the orbits of the eight principal planets, Smithsonian Contributions to Knowledge, vol. XVIII,* 1873.

This celebrated paper passed under the scrutiny of Professors Newcomb and Hall, of the Naval Observatory, by whom it was recommended for publication, and is justly rated as the most valuable of the early researches on the Secular Variations of the planets.

It is divided into five sections: 1. On the Secular Variations of the Eccentricities and Perihelia; 2. On the Secular Variations of the Nodes

and Inclinations; 3. On the positions and Secular Variations of the orbits, when they are referred to the Invariable Plane of the Planetary System; 4. On the Precession of the Equinoxes and Inclination of the Ecliptic; 5. On the Tabular Values of the Elements of the Orbits of the Planets.

Accordingly, it will be seen that Stockwell's early researches on the secular variations of the eight principal planets attained a classic standard, and have been used by all subsequent investigators. After the orbits of these planets had been further improved by the later researches of Leverrier, Newcomb and Hill, some slight improvements became possible, but in the main Stockwell's results have stood the test of time remarkably well.

(B) *Theory of the Moon's Motion,* 4-*to. Philadelphia,* 1875; ***2nd edition,*** 1877; ***3rd edition,*** 1881.

The author forms the general differential equations of the motion of the Moon, discusses the theory of its elliptic movement, and calculates the variations of the arbitrary constants. In a general way he follows Laplace's methods, and considers that the equations which he presents are capable of giving the coördinates of the Moon more directly and more simply than any combination of the general differential equations previously employed. As a practical result he believes he discovered two equations of the 3rd order of short period, as well as several terms of long period, depending on the action of the Sun and on the obliquity of the Earth's axis, which had escaped the attention of his predecessors.

It has long been recognized that Dr. Stockwell followed methods for calculating the motion of the Lunar Perigee which Dr. G. W. Hill and others disapproved as lacking in rigor. It will be recalled that the motion of the Lunar Perigee has presented difficulties for two centuries, and was left incomplete by Newton and Clairaut. At the time a considerable controversy on this point arose, and the scientific world inclined to the side taken by Dr. Hill. During the last 30 years Professor E. W. Brown has investigated the whole problem of the Moon's Motion, along the lines laid down by Hill, and in 1920 published elaborate *New Tables of the Moon's Motion,* in three volumes. (The University Press, Cambridge, England.)

It will be remembered that in 1909, after researches on the Moon's motion extending over 40 years, Professor Newcomb pronounced the movement of the Moon somewhat irregular and defiant of the Newtonian Law. Brown's researches threw no light on this troublesome question, which had even bewildered Laplace himself, over a century ago.

But in 1916 I discovered that the Sun's gravitational action on the Moon was slightly decreased near the time of Lunar Eclipses, owing to the interposition of the Earth's solid mass in the path of the Sun's gravitational action. Thence arose the *Fluctuations* of the Moon's mean motion established by Newcomb, from observation, and shown to re-

cur in periods of about 275 years and 60 years. The theoretical periods found by me lead to *Fluctuations* of the Mean Longitude in 277.6 years, 61.7 years, and 18.03 years.

As the writer's researches on the Moon's *Fluctuations,* 1916-17, are confirmed by Majorana's physical experiments* at Turin, 1919, on the decrease of the Earth's gravitational action when a layer of mercury is symmetrically placed about one of two equal leaden balls, otherwise perfectly balanced, it is now recognized that the Moon's motion must be disturbed when the body of the Earth is interposed in the path of the Sun's action, as at the time of Lunar Eclipses.

Accordingly it thus appears that although our knowledge of the Moon's Motion is slowly improving, we cannot expect the whole truth to be unfolded by orthodox methods. In 1914 Professor Brown thought a screening effect due to the interposition of the Earth could not occur; yet within two years my proof was forthcoming, and the effect could not be denied.

Now in the same way, we cannot be quite sure whether Professor Stockwell's processes of calculation for the motion of the Moon's perigee are allowable or not. We only know that Stockwell's processes are not orthodox, yet as orthodoxy is not the process of discovery, we cannot be sure that they do not contain the germs of important discoveries. The future alone can decide this question, and owing to the small number of persons who specialize in the Lunar Theory, it may be some time before a final decision is attainable.

It usually happens in Science that orthodoxy is popular and encounters little opposition. Therefore opinions once in vogue may persist for a very long time, till overthrown by a genius of greater power and persistence.

These remarks apply especially to the Theory of the Tides, which is not yet satisfactory, in spite of all that has been done on this subject since the publication of Newton's *Principia,* 1687.

In his last years Dr. Stockwell was occupied with a new *Theory of the Tides,* which impressed me as very condensed, and as offering perhaps a very *practical solution* of this difficult problem. Devised along somewhat similar lines the very practical co-tidal maps published by the late Mr. Rollin A. Harris, of the U. S. Coast Survey, appealed to the great Poincaré, who considered that they might be of decided value in dealing with the complex motion of the irregular and landlocked seas covering our globe.

Many of these great questions in natural philosophy still await their final solution. And just as the Greek Poet Sophocles warns us to count no mortal happy till he shall have passed life's borders free from pain, so also, when we study the history of Science, we are impressed with the varying fortune of scientific opinion in successive ages. What one

*Published by the Academy dei Lyncei, Rome, 1919.

age accepts another age may overthrow, until final and conclusive proofs are at length obtained.

In general philosophers are esteemed according to the sincerity with which they persist in the search for Truth. Newton and Laplace each gave over 60 years to Science, and traversed and improved the theory of many of the great phenomena of the world. Our venerable Dr. Stockwell has followed worthily in their footsteps! For nearly seventy years he cultivated with vigor, originality and conscientious effort, the improvement of Celestial Mechanics, in its various branches; and his efforts were crowned by numerous advances which add lustre to the age in which he lived.

If he had lived in former centuries he would have been the associate of Newton and Laplace, who laid and finally established the foundation of the Theory of Universal Gravitation. If he had lived in the age of Archimedes, Apollonius and Hipparchus, he would have added lustre to the Alexandrian School of Astronomy. At Cleveland, Ohio, he witnessed the celebrated experiments of Michelson and Morley, on the stagnation of the Aether about our moving Earth, and himself cultivated and adorned nearly every department of the Science of the motions of Heavenly Bodies.

Dr. Stockwell was preeminently a true philosopher—happy in his researches, and seeking no reward but the noblest of all rewards—the advancement of Truth. Ptolemy's designation of Hipparchus as a 'labor loving and truth loving man,' ἀνήρ φιλόπονος καὶ φιλαλήθης, might appropriately be applied to Dr. Stockwell.

He corresponded on stationery bearing the imprint of the busy bees, working away at the hive. The bees had no time for idleness, neither had Dr. Stockwell! When past his 87th year he once wrote to me that he had been to visit his son in Kansas, the first vacation of his life.

Dr. Stockwell was of mild and gentle manner, and moved about with the air of a genuine philosopher. I remember meeting and conversing with him at a session of the American Association for the Advancement of Science, some twenty-five years ago, and he gave me distinctly this gentle and noble impression.

(viii) *Account of Dr. Stockwell's family, and of his friends in Cleveland.*

As pointed out above, Dr. Stockwell was married, on Dec. 6, 1855, to Miss Sarah Healy, a very estimable young lady, who had lived about ten years with his aunt and uncle at Brecksville, Ohio. An account, written by one who knew best the happy circumstances of Dr. Stockwell's domestic life, is here added because it is inspiring and worth preserving.

"When John Nelson Stockwell in 1844 at the age of twelve (12) years, went to live with his uncle, Oliver Edgerton, in Brecksville, Ohio, he found there a foster daughter, Sarah Healy, a year younger than

himself. These two young people lived as brother and sister for about ten (10) years. Then, just when they never knew, but most naturally, they discovered that a different kind of love had grown up between them. They were quietly married in 1855, and continued to live in the same home with the same good uncle and aunt for sixteen (16) years longer. This old home was very dear to them, and they revisited it many times. The accompanying picture was taken on the steps of this home forty years after they moved away. The love which developed in the intimate life of the boy and girl had a foundation so strong that

PROFESSOR AND MRS. JOHN N. STOCKWELL, AT THEIR OLD HOME, BRECKSVILLE, OHIO, WHERE THEY LIVED FROM 1844 TO 1870. FROM A PHOTOGRAPH TAKEN ABOUT 1910.

it was never weakened by the misfortunes or griefs of the sixty-one years of their married life. Both were domestic in their tastes and each was the complement of the other. The mother was the one who planned and managed and cared for the large family, leaving the father free to carry on his scientific work. Never did a mother live more solely for her home, her husband and her children. After the children were all married and gone from home, the life of the father and mother seemed more and more to be that of two young lovers. Both were blessed with perfect health, so that up to the time of the mother's death at the age of eighty-three (83) it had been possible for them to live alone together. She was thus free to care for his every want and comfort. Old age brought nothing but continued happiness

to them. Her last thought was for her husband whom she had hoped to care for as long as he lived."

A few lines, found on an old envelope and evidently written soon after she left him, beautifully express his regard for her:

"My household Divinity for more than sixty years has departed, and I am now living in the midst of loneliness and solitude. I no longer receive the accustomed greeting of sixty years at the door when I return from any temporary absence; but am welcomed only by perpendicular walls and darkness. I find it a new and terrible experience."

The family consisted of six children, of whom a brief record will be of interest.

1. *Ossian Euclid,* born 1859, Brecksville, Ohio. He studied stenography and typewriting, and was in the employ of Standard Oil Co when he died in 1883.

2. *Orison Lincoln,* born 1861, Brecksville, Ohio. He had a high school education, became a practical surveyor and civil engineer in Cleveland, Ohio. He went to Kiowa County, Kansas, in the cattle ranch business, in 1881, and has been in this business ever since; but in addition has been County Surveyor, and County Clerk of Kiowa County, at Greensburg, Kansas, his present home, at various times, and has acquired several thousand acres of land which by increase in value has now made him very well to do. He is one of the prominent citizens of Greensburg, Kansas.

3. *Albert Gould,* born 1863, in Brecksville, Ohio. (He was named for Dr. Benjamin Apthorp Gould, the astronomer, for whom Dr. Stockwell worked.) He had a high school education, and had entered Case School of Applied Science, and was with a surveying party, on a summer vacation in western Kansas, in 1884, when he died by reason of over-exertion. The death of two boys in early manhood, within one year of each other, naturally was a serious blow to the parents.

4. *Edward Ambrose,* born in 1867, in Cambridge, Mass., when the parents were in employ of Dr. Gould. He was a High School graduate, 3 years at Case School of Applied Science, and one year at the University of Michigan. Civil engineer, 1890 to 1894, accountant and Chief of Tax Division of Cleveland, City Auditor's office, 1895 to 1904; Deputy City Auditor 1904 to 1910, Trust Clerk and Asst. Trust Officer, the Guardian Savings & Trust Co., Cleveland, Ohio, 1910 to date.

5. *Netta Augusta* (now Mrs. Walter S. Sapp), born Brecksville, O., 1869. She was a High School graduate and graduate of Wellesley College, Wellesley, Mass., in 1891. Became a teacher in high school and married Walter S. Sapp in 1895. Mr. Sapp is a bond and investment security salesman residing in Cleveland, O.

6. *John Nelson, Jr.,* born Cleveland, Ohio, 1872. High School graduate, also a graduate of Western Reserve College and Cornell Law

School, Practising Attorney in Cleveland, since 1896. Has been prominent in public life since his admission to the Bar, as member of Board of Education, also Ohio Legislature, as Representative, and as State Senator, and as assistant City Solicitor and as City Solicitor of Cleveland for several years ending about 1915.

Dr. Stockwell had lived so long in Cleveland, and was so greatly respected by the most eminent citizens, that we add a few extracts from correspondence now in my hands.

(A) Dr. Chas. S. Howe, astronomer, and President of the Case School of Applied Science, writes that Dr. Stockwell was the first Professor of Mathematics and Astronomy, serving from 1881 to 1888, when he gave up teaching to devote his entire time to research. Dr. Howe continues:

"Dr. Stockwell was a well-known figure around the colleges of Cleveland, and before the city became so large he was well-known in the city. Within the last two or three years he frequently came to my office, seeming to take some pleasure in talking things over with me, although I was not able to appreciate much of the work that he was doing in regard to the tides and the moon. A few days before his death he came in to return a book which I had loaned him from our library, and at that time spoke of the work he was doing as though he were carrying it on as easily as a man of fifty might do. He had a very gentle, kindly way of speaking in regard to all matters connected with his profession and the men who were serving in astronomical lines, and took a very great interest in everything pertaining to Astronomy. It seemed so strange to see a man of his age continuing his work and apparently in such perfect health that we always rejoiced when we found him able to make us a call."

(B) Dr. Chas. F. Thwing, President of Western Reserve University, Cleveland, writes the following interesting note:

"Dr. Stockwell I have known for about thirty years. Our talks about his studies and researches were numerous. He always impressed me as one of nature's great characters. His intellect was of a very high order of power, and this power he used in a powerful way. His heart was big and noble. There was in him at all times a certain giant-like quality, which set him quite apart from us common men. One felt, almost instinctively, that his thoughts were among the stars. His life seemed to have its orbit in some other system than our own. Yet he was so companionable, so loving and so loved. He was thoroughly human."

(C) Dr. W. R. Warner, of Warner & Swasey, the celebrated builders of the greatest telescopes of our time, sends the following account of Dr. Stockwell's life and labors in Cleveland:

"Our dear Dr. Stockwell, who died last month, used to show me let-

ters, which were a great encouragement and help to him. For the last forty years, which covers my entire residence in Cleveland, it has been one of my special pleasures to render Professor Stockwell every aid in my power. When he needed drawings made, I made them for him, and when he required models to illustrate his work, it has been my pleasure to make them too. I have done my best to be of real help and service to him, but on these lines, I have not been very successful, from the fact that I am not a mathematician, and therefore I have been unable to follow him intelligently in his investigations and in his work. He has been very patient in trying to explain to me the difficulties of the old theories relative to the tides, and I could partially understand the difficulties, while I could not understand his solution of the problems. I have tried my best to get the leading astronomers to look with favor on Professor Stockwell's investigations. During several recent years I have urged upon Professor Stockwell the necessity of getting his papers in definite condition so that his work could be taken up by astronomers in the future. He used to quote to me the statement attributed to Kepler, when the astronomers of his time would not accept his discoveries as fact, and he said, 'I can well wait a century for a believer, since God has waited six thousand years for an observer'. Professor Stockwell never lost courage even though he did not find astronomers who would publish his theories and work with him. I would feel under great obligations to you if you will write me a personal letter telling me your views relative to Professor Stockwell's investigations.

"The fact that the tides are as far as possible away from the old theories, and that they are just where they ought to be according to Professor Stockwell's theories, would seem to me a strong argument in favor of his work which has not been accepted by the astronomers. I wish I could understand these problems as well as I think I do the problems in mechanics, with which I have been working all my life."

(D) Dr. Charles F. Brush, the celebrated electric inventor, gives the following beautiful picture of Dr. Stockwell's daily life in Cleveland:

"I am glad to offer tribute to the memory of Professor Stockwell, and can only regret that my mathematical training was never sufficiently profound to follow him in his excursions into the realm of higher mathematical astronomy, in which he found such great joy. It has been my privilege to have personal acquaintance with Professor Stockwell for thirty or forty years, and during the last few years he has honored me with frequent brief visits at my office. His personality has always been so charming that I have been ever ready to drop all business affairs during his visits for the sake of enjoying intercourse with him, always on astronomical subjects. While we did not always agree on the application of Newtonian mechanics to Dr. Stockwell's problems,

we always had delightful discussions, which never failed to leave a pleasant remembrance. Dr. Stockwell's personality was so lovable, his character so fine and his persistent pursuit of truth so notable as to inspire always sentiments of admiration and high appreciation."

Among Professor Stockwell's other illustrious friends in Cleveland, mention should be made of the Honorable Myron T. Herrick, former Governor of Ohio, and more recently Ambassador to France. But for Mr. Herrick's absence in Europe he would have joined in this testimonial to Cleveland's most celebrated man of Science, and one of the leading astronomers of our age.

Professor A. A. Michelson, the eminent Physicist, was for some years resident in Cleveland, at the time of the celebrated Michelson-Morley experiment, in 1887,—and always had an affectionate recollection of his illustrious associate in Astronomical Science.

Dr. Stockwell's life was one of extreme simplicity. His work was done methodically, without show, or any extravagant tastes. He never had a cross word for any one, cared little for amusements, lived quietly and devotedly with his wife and family, and thus was a true philosopher of the noblest type.

When some astronomers rejected Dr. Stockwell's conclusions respecting Chronology, Dr. Gould always remained steadfast in his support. And thus till his death in 1896, Gould continued to publish his papers in the *Astronomical Journal,* because of his life-long attachment to Dr. Stockwell, and the desire to give a fair hearing to his side of the question.

Dr. Gould knew history well enough to realize that the Truth is only found among the errors of the wise; and that if conscientious effort be not upheld, progress comes to an end. It is seldom that any age can be an impartial judge of the works it brings forth.

It is probable that Dr. Stockwell left a good many valuable papers unpublished. One of his researches of 1918, on the *Maximum Lunation,* in which Stockwell notably improved the Lunar Methods of Dr. G. W. Hill, on this subject, happens to be in my hands; and I shall communicate it to the *Astronomische Nachrichten,* the chief International Journal of Astronomy, so that it may be accessible to investigators generally.

It is to be hoped that Dr. Stockwell's family will safeguard his other unpublished manuscripts, till time shall determine their scientific value. They ought to be carefully listed and classified, and a due record made of them in the chief Scientific Libraries of Cleveland, which Dr. Stockwell did so much to develop.

The city of Cleveland may well take pride in the memory of Dr. Stockwell's life and discoveries. It will be a long time before we again meet with so humble and so noble an investigator in the pure Science of Astronomy. He has set an example of devotion to Truth which few

will ever approach, perhaps none surpass. Thus the Stars in their courses, by the new problems perpetually arising, will preserve his memory while philosophers continue to explore the great secrets of the Physical Universe.

Mare Island, California.

HALOS.

By EDGAR WOOLARD.*

Sun-dogs or mock suns, and colored rings around the sun or moon, are more or less familiar to everyone; they have been regarded as indications of the coming weather ever since the time of the Chaldeans.[1]

These phenomena are results of the sun or moon being viewed through thin clouds. Clouds, as everyone knows, are caused by the cooling of moisture-bearing air, so that some of the invisible water vapor condenses into minute droplets which float in the atmosphere. It is obvious, however, that clouds which are formed at low temperatures, such as prevail at high levels in the atmosphere the year round and at all levels during the winter in temperate and polar latitudes, cannot, except under unusual circumstances[2], consist of *water* droplets. but must be composed of *ice crystals* instead.

Now, when the light of the sun or moon shines through a thin cloud which is composed of water droplets of the right size, the light which passes *between* the droplets is *diffracted;* the result is a bluish or greenish aureole surrounding the luminary, outside of which aureole may be a brownish red ring of considerable width; or else the luminary may be surrounded by *one or more series* of partial or complete rings of various diameters—usually small—more or less distinctly colored. In all such cases *the red is on the outside of the ring*, farthest from the source of light, and whatever other colors may be visible follow in prismatic sequence with *decreasing* distance from the luminary. *All such prismatically colored rings in which the red is farthest from the sun or moon are called coronas,* and will not be considered further in the present paper. Aureoles and coronas are very common about the moon, but would be even more commonly seen about the sun if the intense illumination were cut down by a dark glass or black mirror.[3]

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* Published by permission of the Secretary of Agriculture.

[1] G. Hellmann, *Quar. Jour. Roy. Met. Soc.*, **34**, 223, 1908; W. J. Humphreys, *Pop. Sci. Monthly*, **78**, 437-439, 1911.

[2] See e. g., G. C. Simpson, "Coronae and Iridescent Clouds," *Quar. Jour. Roy. Met. Soc.*, **38**, 291-301, 1912; here is recorded an observation of an Antarctic fog consisting of supercooled water droplets at a temperature of —29° C.

[3] On the theory of coronas, see W. J. Humphreys, "Physics of the Air."

It has been shown that no diffraction *color* effects will be produced by the light which passes between ice crystals;[4] but the light which passes *through* the crystals is *refracted* and gives rise to *halos*. The latter include the *large* colored rings about the sun, in which *the red is nearest the luminary,* and any other colours which may be visible follow in prismatic sequence with *increasing* distance from the source of light.

Although it was suggested by Mariotte as early as 1686 that halos are due to the refraction of light by floating ice crystals in the atmosphere, this explanation was long held in doubt. However, the increasing number of instances (especially in high latitudes) in which the whole air was filled with minute spiculae and crystals of ice at the same times that sun-dogs and halos were visible, soon forced its truth upon everyone. Halos are very common in polar regions; there, and also in temperate latitudes during the winter time, the clouds which give rise to halos are frequently at low elevations—or during a cold wave the atmosphere down to the ground may be filled with falling ice needles, no real cloud existing; but in the tropics, halos are produced only by the high cirrus clouds, many miles above the ground, where reigns eternal cold.

The beautiful forms into which water freezes, as evidenced by frostwork and snow-flakes, are familiar to everybody. Among the innumerable complex forms which have been observed, however, there are two, the simplest ones, from which all the others may be, and probably are, built up. These are: the six-sided column or long, thin needle, shaped, e. g., like a hexagonal lead pencil; and the six-sided plate, like a very thin cross-section sawed out of a lead pencil. There is reason to believe that these are the forms that predominate in clouds which give rise to halo phenomena.

As these minute crystals fall through the air, they tend to assume certain definite positions; but they are continuously rotating or vibrating about these equilibrium positions, and of course in turbulent air they lie more or less at random in every respect. Light falling upon one face of a crystal and emerging from another face will be bent, or refracted, in accordance with familiar optical laws; and if, after such refraction, the ray enters the eye of an observer, the latter will see the source of light displaced in the direction in which the ray enters his eye. With so many different faces to each crystal, and so many different positions of the falling crystal possible, it is obvious that if *parallel* light from the sun or moon falls *upon* an extensive cloud of crystals distributed at random, beams of light will *emerge from* the cloud in *many different directions*. No one crystal will stay in the same position long, but as soon as it departs from this position, another crystal has, on the average, come into the same position, and hence at any one

[4] Simpson, *op. cit.;* S. Fujiwhara and H. Nakano, "Notes on Iridescent Clouds," *Jour. Met. Soc. Japan,* June, 1920.

instant there are a great many crystals in each possible position; all that portion of the incident light which falls upon crystals in this position will be refracted in a certain way; and all that light which falls upon crystals in another position will be refracted in another way. With a sufficiently extensive cloud, then no matter where the observer is, there will always be some crystals of each group so situated that the refracted light enters his eye. In addition, a great deal of light is also reflected, both externally and internally, and this light also gives rise to halos, which are white; the halos due to refraction are prismatically colored, because the different colors constituting the incident white light are not all bent by an equal amount.

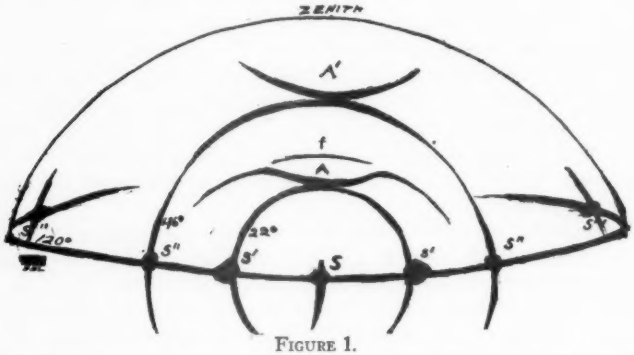


FIGURE 1.

The Bouder (Colo.) Halo of January 10, 1918.—Original sketch by E. W. Woolard. From *Monthly Weather Review*, June 1920.

The final result of looking towards the sun through a cloud of ice crystals is exemplified by Figs. 1-3. It is seldom, however, that so many different arcs and circles are visible at one time. Usually the halo is very simple—a couple of sun-dogs, perhaps, and one or two circles or parts of circles. The most common halo is the circle of 22° radius, existing alone. When of no great intensity, this ring appears white, but when it is more strongly developed the edge nearest the sun is red, and if it is very brilliant, orange, yellow, and, under favorable circumstances, green, follow in order. The inner edge is sharp, and the sky within the ring comparatively dark; the outer edge is diffuse, and the sky illuminated with a white glare to some distance beyond it. This 22° halo often appears complete, but usually only in the form of more or less extensive fragments of varying distinctness. At Paris it is visible about one day out of every three. In spite of its frequency, an inexperienced observer may have some difficulty in finding it for the first time, for it is seldom brilliant.

Just which of the various arcs shown in Figs. 1-3 will be present in any other given halo display, and their brilliancy, are determined by the altitude of the sun; the number, distribution, and predominating

forms of the crystals composing the cloud; and the degree of quietness of the atmosphere. These displays did not include all the forms that have been observed before at different times—Fig. 4 attempts to be such a composite, "ideal", halo, although it, too, omits some very rare forms; conversely, Figs. 1-3 include some elements that are extremely rare—the "Parry Arc" in Figs. 1-2 has been reported only three times, and the secondary parhelic circle in Fig. 3 appears to have been seen only this one time. The well known French meteorologist Renou

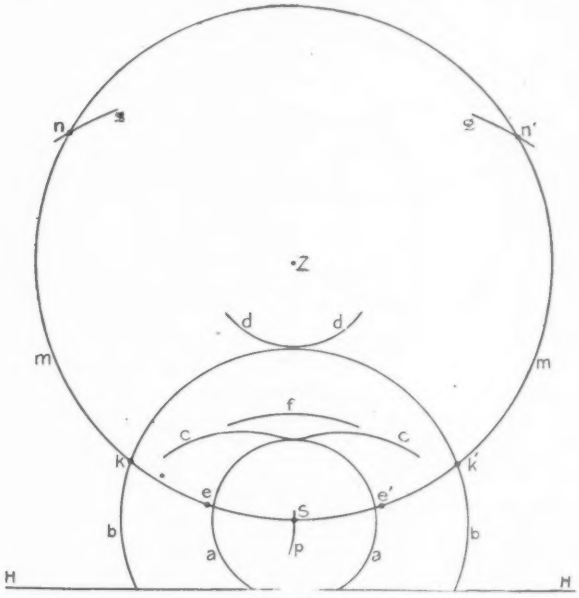


FIGURE 2.

The Boulder (Colo.) Halo of January 10, 1918.—Conventional drawing *showing the customary method of projection*. HH, horizon. S, sun. Z, zenith. Elevation of sun, 19° 50′; temperature, —4° F.; atmosphere very quiet, and filled with falling ice needles.

Refraction phenomena.—aa, *Halo of* 22°; e, e′, sun-dogs, technically known as *parhelia of* 22° (they are on the 22° halo when the sun is at the horizon, and outside the halo at all other solar altitudes); CC, *upper tangent arc* of halo of 22°; f, *Parry's upper arc* (rare; should be carefully observed if seen); bb, *Halo of* 46° (somewhat rare; if seen, it should be observed whether it consists of arcs symmetrically placed, as in Fig. 1, or of a uniform band of light); k, k′, *parhelia of* 46° (rare); dd, *Circumzenithal arc* (brilliantly colored).

Reflection phenomena.—p, *sun-pillar* (the curvature is unusual); mm, *parhelic circle* (white, and parallel to horizon at altitude of sun); n, n′, *paranthelia of* 120°; gg, *paranthelic arc* (rare).—From *Monthly Weather Review*, June 1920.

watched ceaselessly for halos during more than half a century, nevertheless he never saw the oblique arcs of the anthelion, Fig. 3, not to mention many another rarer form.

The circumzenithal arc sometimes exists alone, and because of its brilliant coloring is frequently mistaken for a rainbow.

All these various forms can be explained by the laws of refraction and reflection of light in our two kinds of ice crystals—the hexagonal rod and hexagonal plate.[5] But some of the rarer ones have been so

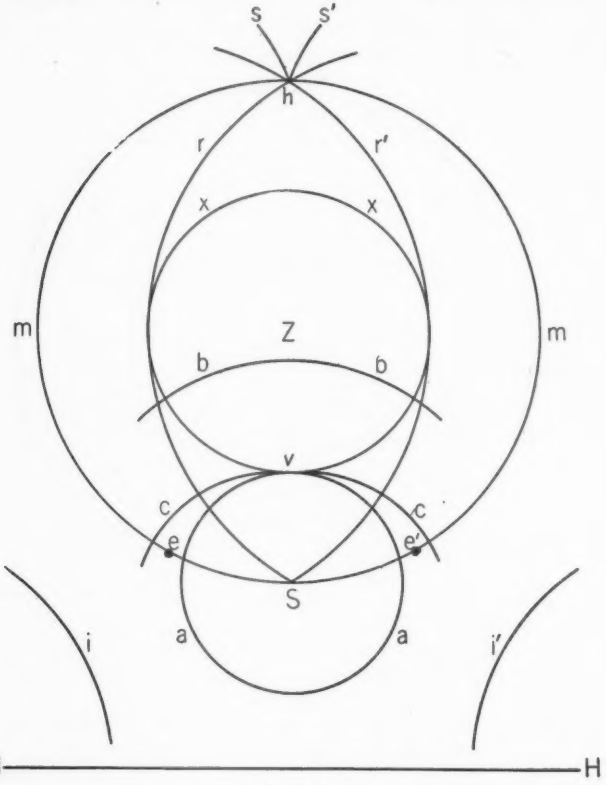


FIGURE 3.

The Ellendale (N. Dak.) Halo of March 8, 1920, observed by F. J. Bavendick and W. H. Brunkow.—HH, horizon; S, sun; Z, zenith, aa, halo of 22°; e, e', parhelia of 22°; cc, upper tangent arc of halo of 22° *(note how this differs from the same arc in Fig. 2, on account of the different altitude of the sun);* bb, portion of halo of 46°; i, i', *infralateral tangent arcs* to halo of 46° (rare; should be very carefully observed and measured if seen); mm, parhelic circle; h, *anthelion* (or counter-sun; white); r, r', wide-angle oblique arcs of the anthelion (very rare); s, s', narrow-angle oblique arcs of the anthelion (very rare); v, vertical parhelion; xx, apparently a secondary parhelic circle, caused by *v* acting as if it were itself a source of light (very rare). At this altitude of the sun, it is impossible for the circumzenithal arc to form.—*Monthly Weather Review*, June 1920.

[5] C. S. Hastings, "A General Theory of Halos," *Monthly Weather Review*, June 1920.

infrequently and inadequately observed that the precise mode of their formation is still in doubt. The theoretical explanation of the formation of each element of the halo complex cannot be attempted in this paper, for it is a long, tedious, complex and mathematical subject; and besides is readily accessible to any one interested.[6]

Good observations of well-developed halo displays are urgently needed. One observes but poorly that with which one is unacquainted;

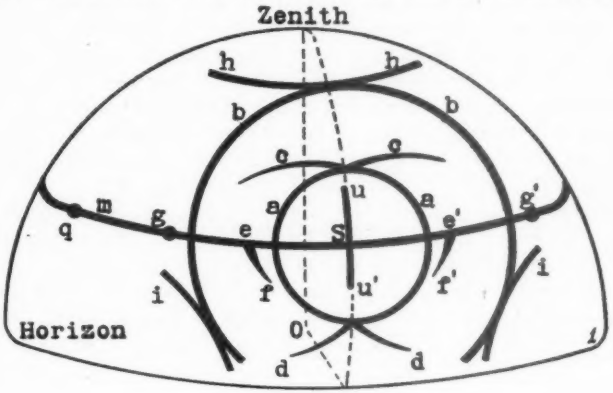


FIGURE 4.

Ideal halo: S, sun; a, halo of 22°; b, halo of 46°; c, upper tangent arc to halo of 22°; d, lower tangent arc to halo of 22°; e, e', parhelia of 22°; f, f', *Arcs of Lowitz* (extremely rare; should be carefully observed if seen); g, g', parhelia of 46°; h, circumzenithal arc; i, infralateral tangent arcs to halo of 46°; m, parhelic circle; q, paranthelion of 90° (very rare). O, observer.—*After* BESSON.

the object of the present article is to acquaint observers with the general appearance of halo displays. Observations on halos are usually more or less worthless—the majority of them are quite devoid of interest since they pertain to phenomena which the observer thought extraordinary, but were really nothing other than more or less brilliant manifestations of well known and completely understood phenomena. Sometimes there are among the described forms, curves whose form is not yet well defined or that appear to be new ones, but unfortunately the descriptions of those portions of the phenomenon whose identity is undoubted almost always reveal such inaccuracies that they greatly weaken our confidence in the observer's other descriptions.[7]

In observing halos, record the successive phases of the phenomenon, stating the exact time of occurrence of each phase together with the corresponding variations in the appearance of the sky; state the kind of time being used. If an unknown element appears in the complex, first

[6] W. J. Humphreys, "Physics of the Air."

[7] An excellent manual for halo observations is L. Besson, "The different forms of halos and their observation", *Monthly Weather Review*, July 1914.

examine its form, its position with reference to the sun and to the other luminous phenomena, its colors and their arrangement, and the time of appearance. *At once make an accurate sketch of the display,* and record the time; never combine in one drawing phenomena observed at different times. The individual peculiarities, colors, etc., of each element of the complex may be noted, and detailed drawings made of any noteworthy appearance. If instruments are at hand, *carry out angular measurements of each element*—altitude, azimuth, mutual distance, radii of arcs, etc., recording the time of each measurement. The lenses of the instrument will have to be removed for this work; pointings may be made on a definite color, or in succession on each color. Useful measurements may be carried out even without instruments, by noting relations to terrestrial objects, and afterwards setting up an instrument at the same spot. It is necessary to specify carefully whether recorded intervals are in azimuth or on arcs of great circles.

Lunar halos, being faint, seldom show much, if any, coloring. The terminology given in the legends to Figs. 1-4 requires to be slightly modified in the case of halos due to the moon—the sun-dogs, or parhelia, become *moon-dogs,* or *parselenae;* the parhelic circle then is known as the *parselenic* circle, the anthelion as the *antiselene,* etc.

THE LIMIT OF THE ASTRONOMICAL TELESCOPE.

By G. A. SHOOK.

PART I.

RECTILINEAR PROPAGATION OF LIGHT.

Whatever the ultimate nature of light may be as far as our telescope is concerned it is sufficient to consider it a simple wave motion in which the displacement of the medium, through which it passes, is at right angles to its direction of propagation. The distance from crest to crest is called the wave-length and the wave-length of white light is roughly 0.00005 cm. If two waves pass through the same point in the medium in such a way that the crest of one coincides with the crest of the other the result will be a wave of greater amplitude, i. e., we will have constructive interference but if the trough of one coincides with the crest of the other we will have destructive interference and therefore at this point the medium will not be displaced. In a medium in which the velocity of propagation is the same in all directions, the wave spreads out from a point source somewhat as indicated in Fig. 1.

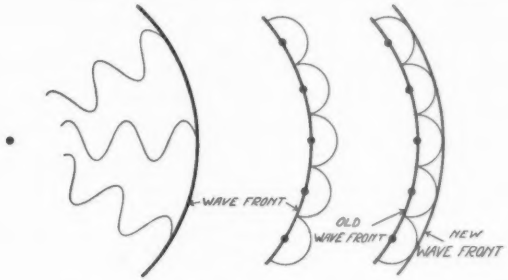


FIG. 1. Wave-front and secondary waves.

A surface drawn through all the points, which are in the same phase of vibration, is called a wave-front. In order to better explain reflection, refraction, etc., Huygens considered every point in a wave-front to be a new source of disturbance sending out secondary waves as shown. The envelope of these secondary wavelets constitutes the new wave front at any point.

To explain why light does not bend around an object, as it should if these secondary waves exist, Fresnel imagined the wave-front to be divided into zones in the following manner:

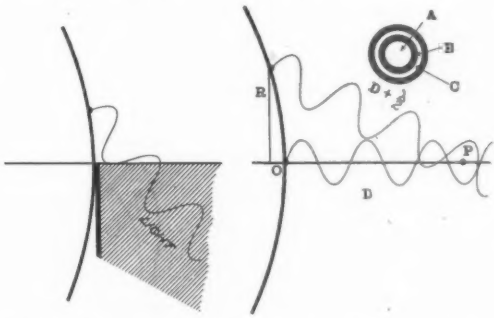


FIG. 2. The absence of light in the shadow is due to interference of the secondary wavelets.

Let P be a point on the axis of the wave-front at a distance D from the pole of the wave O. Describe a circle on the wave front of radius R such that the distance from any point on this circle is just one-half of a wave-length greater than D. Waves from this circle will interfere with waves from the pole but all the light from this region, A, which is called a half period zone, will not be annulled. Now suppose we draw another circle about O such that every point upon it is at a distance $D + \lambda$ from P, where λ is the wave-length. The region B constitutes the second half period zone, while C is the third. In a similar manner

the fourth, fifth, etc., zones may be constructed, so that the entire wave front may be divided into zones.

Now due to the fact that on the average the light from one-half period zone is one-half a wave length behind that from the next inner zone most of the light is destroyed by interference so that the effect of the whole wave is somewhat less than the first zone.

For a plane wave or one of very small curvature the radius of the first zone is given approximately by the simple relation

$$D^2 + R^2 = (D + \frac{\lambda}{2})^2 = D^2 + D\lambda + \frac{\lambda^2}{4}$$

Neglecting λ^2, which is very small, the radius R becomes

$$R^2 = D\lambda$$

At a distance of 10 meters from a plane wave front, taking λ as 0.00004 cm, R becomes 0.2 cm, while at a distance of 10 cm R is 0.02. It is thus seen that light does travel, approximately, in straight lines since the only effective part of a wave-front is the very small region surrounding its pole, the rest of the wave being destroyed by interference.

THE DIFFRACTION IMAGE OF A STAR.

We are now in a position to investigate the effect of the size of our telescope upon the size of the star image. Consider a wave from a point source S, Fig. 3. When a wave front, plane or convex, passes through a converging lens, the lens by its variable thickness is able to change the curvature of the wave front as shown.

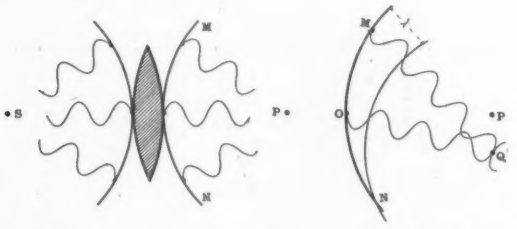


FIG. 3. Interference of waves transmitted through a lens.

In this case every point in the transmitted wave front is the same distance from the point P so that, as there is no difference in phase, every part of the wave front MN is effective. To be sure the transmitted wave is never truly spherical but we will neglect this defect in the lens here. If we consider a point Q not on the axis of the lens, then since Q is not equally distant from all points of the wave front we may have interference. If the path difference between MQ and NQ is just one wave length, then the path difference between MQ and OQ is very nearly one-half wave-length so that the light from the

point M will destroy that from O by interference. It is moreover evident that light from points just below M will be destroyed by light from points just below O so that for this point Q one-half of the wave completely destroys the other half. We are here considering only the waves in the plane of the paper, but if we imagine the figure to revolve about the axis OP we see that, surrounding the point P we would have a dark ring of radius PQ. At a point below Q where the path difference is three-halves of a wave-length we would have some light, for we may here imagine the wave-front divided into three parts instead of two and it will be seen that one-third destroys another third by interference, leaving one-third operative. It is clear therefore that the central bright disc will be surrounded by bright rings, but most of the light is in the central disc and the first two or three rings. This disc and rings are known as the diffraction image of the point source.

The image of a point source is therefore never a point but a disk of finite dimensions surrounded by bright rings of diminishing intensity. This is manifestly of great importance when we consider the images of close double stars.

LIMIT OF RESOLUTION.

We shall now determine, by an approximate method, the relation between the radius of this star image and the dimensions of our telescope.

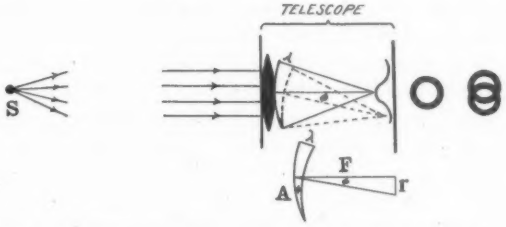


FIG. 4. Diffraction images produced by the telescope.

Consider a star S sending light to our telescope. The distance of the nearest and largest stars is so great that we may consider S a point source. Let the radius of the central bright disk be r, and let the angle subtended by r be ϕ and the diameter of the lens, A. Now since the distance from the lens to the image is equal to F, the focal length of the objective lens, we may write

$$\phi = \frac{\lambda}{A} \quad \text{and} \quad \phi = \frac{r}{F}$$

therefore

$$\frac{r}{F} = \frac{\lambda}{A} \quad \text{whence} \quad r = \frac{F\lambda}{A}$$

It is thus seen that the size of the star image varies directly with the focal length of the telescope objective and inversely with its diameter. It is generally considered that two stars cannot be seen as two, *or resolved,* if the centers of their diffraction disks are separated by a distance less than the radius of the disk. This means that the minimum of one image would just overlap the maximum of the other and they would appear as shown. As a matter of experience, due to unfavorable atmospheric conditions and imperfections in the lenses it always requires a greater separation than this to see the two stars as two.

Taking this as the arbitrary limit of resolution the aperture of the objective, in terms of the angular distance between the two stars, is

$$A = \frac{\lambda}{\phi}$$

If we take the mean wave-length of white light as 0.00005 cm, then since one second of arc is roughly 0.000005 in angular measure, to resolve two stars separated by an angle of one second would require an aperture of

$$A = \frac{0.00005}{0.000005} = 10 \text{ cm (approximately)}$$

That is, the two stars would not be observed as two by a telescope with an objective of less than 10 cm diameter, and since ideal conditions never obtain it would require a somewhat larger diameter than this. The theoretical limit for a telescope the size of Yerkes, 100 cm objective, would be approximately one-tenth second of arc.

Looking at the problem from another viewpoint we get quite surprising results. For example, with a 100 cm objective the angular semi-diameter of the diffraction disk is 0.1″. Let us compare the size of the telescopic image of a celestial object (assuming that a point source would produce a point image) with the actual size of the diffraction disk. The distance to the sun is 93 millions of miles, roughly 10^8 miles, but the distance to the nearest fixed star is probably not less than 5 light years, or since 1 light year is nearly 6×10^{12} miles, about 30×10^{12} miles, while the distance to Denebola is about 25 light years or 150×10^{12} miles. Now, although the diameter of our sun is 866,000 miles, if it were only 1 light year away its angular semi-diameter would be very much smaller than the radius of its diffraction disk as may be easily shown. Since one radian is about 2×10^5 seconds of arc the angular semi-diameter in seconds would be

$$\phi = \frac{(\text{radius of sun}) \times 2 \times 10^5}{\text{one light year}} = \frac{433{,}000 \times 2 \times 10^5}{6 \times 10^{12}} = 0.014''$$

As stellar distances go one light year is rather small, so that, if the sun were as far away as Denebola the semi-diameter would of course

be very much smaller. At this distance, due to diffraction effects, two celestial bodies the size and brightness of our sun could just be distinguished as two separate objects in our best telescopes even if they were as far apart as the earth and the sun for then the angle between them would be

$$\phi = \frac{(\text{distance of sun to earth}) \times 2 \times 10^8}{25 \text{ light years}} = \frac{10^8 \times 2 \times 10^8}{25 \times 6 \times 10^{12}} = 0.13''$$

Many of our telescopic stars are, however, at much greater distances than these considered, indeed some are doubtless thousands of years away. At a distance of 1000 years two suns, to be distinguished as two in a 100 cm telescope would have to be separated by a distance as great as that between the sun and Neptune, i. e., 2792 millions of miles.

Wheaton College.

(To be continued.)

TWENTY-FOURTH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY.

(Continued from page 532.)

ABSTRACTS OF PAPERS

PRELIMINARY WORK FOR THE TOTAL ECLIPSE OF SEPTEMBER 10, 1923.

By JOAQUIN GALLO.

When "The International and Pan-American Congress" was held in the City of Mexico in 1910, Professor David Todd presented an article entitled "Three Centuries of Total Eclipses of the Sun in Mexico" mentioning all the visible eclipses in this country, during three centuries. The first eclipse that he points out, as taking place in the twentieth century, is the one of September 10, 1923. At the close of 1918, I thought convenient to prepare the observation of this eclipse, giving the first steps to compute approximately the track of the shadow and to choose some places in order to set meteorological stations and to observe the weather conditions. Some years ago, astronomers felt the necessity of knowing the weather conditions at the moment of the eclipse with the nearest precision. The reports of Dr. Campbell, and also those of the astronomers who undertook long journeys to observe

these phenomena, made me feel the advantage of making meteorological observations on the same date and hour of the eclipse, at least four years before the date above mentioned, in convenient places and near the central line.

The National Astronomical Observatory of Tacubaya would undertake the preparation of these preliminary works, and this was my idea, when the computations of the eclipse by the first determinations of the sun and moon positions began. Though this computation was not exact, it was sufficiently approximated to know the places of centrality, the hours and the width of the shadow in crossing the Mexican Republic; when it was finished, the results were published in POPULAR ASTRONOMY of March, 1919, and also a short article on the matter written to call the attention of the astronomers abroad that the National Astronomical Observatory of Tacubaya will take special care in preparing everything necessary in connection with this eclipse.

Drs. Campbell, Mitchell and others wrote suggesting to me the advantage of having atmospheric observations from the 1st to the 20th of September in each year at the hour of the eclipse, and so I asked for the establishment of some meteorological stations at Ensenada de Todos, Santos, Guaymas, Cuencamé, Catorce, Cerritos, Matehuala, which will show, with those of Hermosillo, Tampico, Champotón and Payo Obispo, the weather conditions along the central line. Ing. Pedro C. Sánchez, Director of the Geodetic and Climatological Department supported my petition to the Minister of Agriculture, who immediately ordered the securing of those observations for satisfying the needs of science. The Director of the Central Meteorological Office, Ing. Octavio Bustamante, gave the necessary instructions to the observers in the places concerned, and the observations began on the 1st day of September, last year, at 1 P. M.

QUANTITY OF CLOUDS FROM 1 TO 5 P. M.

SEPTEMBER, 1919.

(Scale 1 to 10)

PLACES	DAYS 1 to 20	DAYS 9, 10, 11
Ensenada de Todos Santos	5	7
Tijuana	0	0
Hermosillo	3	0
Santiago Papasquiaro	4	3
Cuencamé	10	...
Tepehuanes	6	10
Matehuala	7	10
Catorce	4	7
Cerritos	5	5
Matehuala	6	8
Ozuluama	4	1
Ebano	5	8
Champotón	7	7

It is well known that in the Central Plateau of Mexico, the rainy season begins in May and finishes at the end of September; the cloudy weather is frequent in the first days of September. The adjoining table shows the resumé of observations I refer to, and we can see that only in one place was there 30 per cent of clouds. The results of Tijuana are doubtful. These data were obtained according to the circular addressed by the Meteorological Office, asking for the data of clouds, direction, quantity, wind, dust, fogs, etc., and for some other places, also the pressure and temperature.

I must choose a convenient place, as a seaport, or a place on or near a railway line, to set, if possible, two astronomical stations, one far towards the west, the other one on the Central Plateau or near the coast of the Mexican Gulf; I shall prefer the seaport of Ensenada, in Lower California, or the small ranch of Guadalupe, or the village of Cuencamé, on the Mexican Central Railroad; consequently the meteorological station of Guadalupe will begin to work this year.

I must say that in revising the first computation of the eclipse, I found some errors, which were impossible to avoid; these errors were not of great transcendency, notwithstanding they displaced the central line less than 3′ to the south, according to the comparison got by Prof. Eichelberger, who kindly sent me a copy of his results which will be published in the *American Ephemeris and Nautical Almanac* for 1923.

The tables used in computing the eclipse in Tacubaya were those of Radau used also in Paris for the moon's ephemeris; it seems to me that the corrections with these tables are smaller than those obtained with the Hansen and the corrections by Newcomb. The tables of Brown did not reach me till some months ago. For the sun positions we used the Newcomb's tables. When the recomputations were finished, I saw, that the line determined in Tacubaya is 900 meters north of that obtained in Washington, and that the moment of centrality scarcely differs 5 seconds, for 9^h30^m (G. M. T.).

According to these results, the total eclipse will be visible in the Pacific ocean, in a small part of the United States on the shore of California, between Santa Barbara and Point Sal including Arguello and Concepción; the islands of San Clemente, San Miguel, Santa Rosa, Santa Cruz, Magdalena, San Nicolás, and Santa Catalina, and the region of San Diego, California, are comprised in the shadow. Noticing that the south point of San Clemente Island is only two kilometers off the central line, I hope that this distinguished American Astronomical Society will give in advance reports of the weather conditions of that island to the astronomers throughout the world.

The moon's shadow will cross the Mexican Republic through its greatest extension by the Gulf and by tne Peninsula of Yucatan. The

Chartography Office, belonging to the Geodetic and Climatological Department, is preparing a chart of Mexico, which will contain the places of relative importance, railways, roads, heights, located in the path of totality, and also the data of beginning of the partial eclipse, time and duration of totality, etc. As soon as meteorological observations are finished in 1922 all the data and charts will be published and sent to the observatories, and astronomers will be able to choose convenient stations.

The results of computation, I have the honor to place in the hands of the president of this learned Society, show the elements employed in the forecasting of the eclipse, specially computed for Mexico. In these elements the corrections due to height are not included.

I shall concisely recall the geographic configuration of the country along the central line: From Ensenada to the Gulf of Cortéz (Gulf of California) the region is arid, with hills of 1000 meters height above sea level; the lack of railways and of important cities makes only the Ensenada de Todos Santos a good place for the establishment of an astronomical station.

In the state of Sonora, towards the eastern part of Guaymas and Hermosillo, begins the chain of mountains called Sierra Madre Occidental, with high mountains, inaccessible places, precipices, rivers, till the region where Lerdo, Cuencamé, Matehuala, Guadalupe, are located at a height of 1500 to 2000 meters. Though Tampico is in the zone of totality, it is far from the central line and the duration of totality in that region diminishes to 2^m30^s. The weather is generally cloudy in September.

In the western part of the Peninsula of Yucatan, is the harbor of Champotón nearly on the central line, but aside from its bad meteorological conditions the duration of the totality is very short. In the states of Yucatan, Payo Obispo, and Campeche, the whole region is inaccessible by the luxuriant woods of mahogany, cedar, and chico zapote.

The efforts that both the Mexican Government and the Astronomical Observatory may opportunely make in this eclipse, will be the necessaries to please the scientific parties going there to observe this interesting and famous eclipse, of which Professor Todd says: "And a very famous eclipse it is, too, if we regard its past history according to the 18 years Saros recurrences. For it was at this eclipse in 1851 that the solar corona was first photographed, and at its next return in 1869 the salient discovery of coronium was made with the spectroscope."

The coming eclipse of 1923 is for me a pleasing remembrance, because it is the return of that of 1905, when a special Mexican commission went to Spain in order to observe it, and I had the honor of being appointed as a member of it. The acquaintance with

Professors Miller, Cogshall, and other famous astronomers, was made upon the Castilla lands.

I affirm that on this occasion all kinds of facilities in traveling will be offered by our Government and also by the railroad companies, beating down the fares to a minimum. For longitudes. the Tacubaya Observatory will give a series of signals through the Chapultepec radio station at mean noon, and at night with Greenwich time.

In reporting briefly about the preliminary work made in the Tacubaya Observatory for the total eclipse of the sun of 1923. I do it because it is my duty since I am a member of this Society and also of the Eclipse Committee. I hope it will be benevolently received due to the good will of the American people.

NOTE ON THE 100-INCH HOOKER TELESCOPE.

By George E. Hale.

As compared with the 60-inch reflector, the Hooker telescope should yield the following advantages if used under *perfect* atmospheric conditions:

	Light Collecting Power	Scale of Focal Image	Resolving Power
60-inch reflector	1	1	1
100-inch reflector	2.8	1.7	1.7

Thus the chief gains should come from (1) the possibility of photographing fainter stars and of applying higher dispersion to brighter ones; (2) the greater scale of the focal image, giving better separation of the crowded stars at the center of globular clusters, smaller details in photographs of the moon and other celestial objects, and greater precision in the measurement of stellar photographs and the proper and internal motions of nebulae; and (3) an increase of optical resolving power sufficient, if realizable in practice, to permit the separation of extremely close double stars, beyond the reach of any exisiting means of observation.

The tests thus far applied show that a gain of a full magniture has been obtained in stellar spectrographic work, permitting a marked extension of our observing program, and the inclusion of such interesting objects as the long period variables, forty-six of which have been measured by Merrill for radial velocity, while one (R Aquarii) has been found to show the characteristic nebular lines. In

direct photography the gain is smaller and though it has not yet been accurately measured, it probably does not exceed half a magnitude. However, for somewhat limited fields it has been possible to photograph stars fainter than we had originally hoped to reach. This has been accomplished by the use of a converging lens, introduced by Shapley a short distance in front of the photographic plate, and virtually reducing the focal length of the telescope. In this way a gain of more than two magnitudes over the 60-inch (without such a lens) has been realized.

The full advantage expected from the increased scale of the image seems to have been reached, but this cannot be determined with certainty until much work of measurement has been done. Photographs of the moon taken by Pease show smaller details than do those made with the 60-inch, and the same is true of nebulae. The slides of the moon that accompany this paper do justice to the moon photographs, but those of nebulae are not suitable for purposes of comparison, though the original negatives from which they were made show decidedly smaller details in the case of the 100-inch telescope.

Finally, the application of the Michelson interferometer has not only permitted the full theoretical optical resolving power of the Hooker telescope to be utilized—it is more than doubled under ordinary conditions of observation. A full account of the applcation of this method to Capella is given in a paper by Anderson. More recently an interferometer 20 feet in length having the resolving power of a telescope of 40 feet aperture, has been successfully tested by Michelson with the 100-inch telescope. If used on a sufficiently large scale, this method should permit the diameter of a star to be measured. It is perhaps possible (though this is still very uncertain) that a special form of Michelson's interferometer may prove applicable to the measurement of the distance between stars several minutes of arc apart. Every effort will be made to accomplish this, in view of the obvious advantages of attaining in parallax and proper motion work any such degree of precision as that reached in the case of Capella.

THE MOUNT WILSON PHOTOGRAPHIC MAP OF THE SUN-SPOT SPECTRUM.

By George E. Hale and Ferdinand Ellerman.

The advance copy of the map that accompanies this paper is essentially in final form, though labels must still be attached to identify the several spots represented on the various sections and to give other necessary data. The range covered is from $\lambda 3900$ to $\lambda 6600$, and the phenomena shown are of the most diverse character.

The negatives from which the map was made were taken in the

second order of the 75-foot spectrograph used with the 150-foot tower telescope. They were afterwards enlarged to a scale of one centimeter to the angstrom, in order to show as well as possible the separation of the lines caused by the magnetic field. The polarization phenomena characteristic of the Zeeman effect are recorded on the negatives with the aid of a Nicol prism and compound quarter-wave plate, mounted above the slit of the spectrograph. Thus in a normal triplet, such as λ6173 or λ6303, the red and violet *n* components, which are elliptically polarized in opposite senses, are respectively transmitted by successive strips of the quarter-wave plate.

Only a few of the numerous and complex phenomena shown on the map can be mentioned here:

(1) It will be observed that the separation of the components of lines affected by the field becomes gradually smaller, on the average, in passing from the red toward the violet end of the spectrum. This is due to the fact that, in harmony with Preston's law, the mean magnetic separation is proportional to the square of the wave-length.

(2) The telluric lines naturally show no magnetic effect, and the same is true of the majority of the band lines, which are due to compounds (including magnesium hydride, titanium oxide, and calcium hydride) rendered conspicuous in the spot by the reduced temperature.

(3) All types of magnetic separation found in the laboratory are undoubtedly present, but the intensity of the magnetic field, which does not often exceed 3500 gausses (for λ6173), is usually insufficient to resolve lines having more than three or four components.

(4) The magnitude of the separation is not dependent solely upon the separation observed in the laboratory at unit field-strength, but also varies with the size of the spot and the level in the spot represented by the line in question. Thus high-level lines, like H_2 and K_2, show very small displacements, while many lines corresponding to low levels, where the field-strength is much more intense, are widely separated.

(5) The polarization phenomena agree in general with those observed in the laboratory at similar angles with the lines of force, but there are certain notable exceptions that deserve careful study. One of these is illustrated by the behavior of the *p* (central) component of triplets like λ6173, which may be seen on the map to show small displacements. These would seem to indicate that this line, instead of being single and plane polarized, as observed in the laboratory, consists in the spot of two components, each elliptically polarized in the sense opposite to that of the corresponding *n* component.

(6) The intensities of the spot lines, which in many cases differ widely from their intensities in the solar spectrum, can be largely accounted for by the combined effects of level, magnetic field, and reduced temperature.

The interpretation of the spot spectrum is being worked out with the aid of laboratory experiments, and special provision has been made for the investigation of lines showing exceptional polarization phenomena.

(The map was on exhibit at the meeting.)

THE ORBIT OF THE SPECTROSCOPIC BINARY H. R. 6385.

By W. E. Harper.

This star (α 1900 = 17^h 06^m.1, $\delta = +12°$ 19′, visual magnitude 6.46, type A0) was found to be a spectroscopic binary from four observations made here at Victoria in 1918 and 1919. Twenty-eight additional plates have been secured this season. The spectrum has numerous good lines for measurement, about fifteen on the average being used. The period obtained from connecting up the observations over the three years was 23.245 days and it was felt unnecessary to include this element in the least-squares solution. The probably error of a plate is ± 1.50 km per sec.

The final elements are:

$$P = 23.245 \text{ days}$$
$$e = 0.427 \pm .014$$
$$\omega = 129°.85 \pm 2°.46$$
$$\gamma = +3.51 \pm .30 \text{ km}$$
$$K = 27.67 \pm .45 \text{ km}$$
$$T = \text{J. D. } 2{,}421{,}780.290 \pm .116 \text{ days}$$
$$a \sin i = 7{,}997{,}400 \text{ km}$$
$$\frac{m_1^3 \sin^3 i}{(m + m_1)^2} = 0.038 \odot$$

THE ORBIT OF THE SPECTROSCOPIC BINARY BOSS 5900.

By W. E. Harper.

This star (α 1900 = 22^h 48^m.2, $\delta = +16°$ 19′, visual magnitude 5.72, type K0) was found to be a spectroscopic binary by the writer from the second plate made in the autumn of 1919.

The orbit is based upon seventeen spectrograms measured on the Hartmann spectrocomparator with a spectrum of Arcturus serving as a standard. The period deduced from connecting up the observations of the two seasons was 24.65 days. A plot showed that the observations followed a sine curve so closely that it was decided to consider the orbit circular. A least squares solution for the remaining elements gave:

$$P = 24.65 \text{ days}$$
$$e = 0.0$$
$$\gamma = -12.84 \text{ km} \pm .49 \text{ km}$$
$$K = 33.20 \text{ km} \pm .49 \text{ km}$$
$$\frac{m_1^3 \sin^3 i}{(m+m_1)^2} = 0.094 \odot$$

The low value of the eccentricity is noteworthy. The number of so-called late-type stars with low values for e suggest that in studies of the variation of e with the period, the different types should be treated separately.

THE LIGHT-CURVE OF EROS IN 1914: A CORRECTION TO THE RESULTS PREVIOUSLY PUBLISHED.

By Margaret Harwood.

The period of the variation of the light of Eros in 1914 was announced by the writer at the meeting of this society in 1915 to be $0^d.3064$. The double period found by Bailey in 1903 was $0^d.2196$.

In a recent revision of the magnitudes of the comparison stars used during the opposition of 1914, Comparison Star No. 9 of the sequence was found to be a variable. (See *Harvard Annals* **76**, No. 8, Table I.) Three new comparison stars were selected and Eros was remeasured independently by Miss Mary D. Applegate and by the writer. These two sets of observations agree with one another, but they are not satisfied by the period $0^d.3064$. The period of the new variable star proves to be approximately $0^d.3064$. This accounts for the period previously found for Eros in 1914.

The observations of Eros do not agree with the period of $0^d.2196$ and no other period has been found to fit them. This is not surprising as Eros varied very slightly, if at all, three-tenths of a magnitude being the maximum range.

A CURIOUS EFFECT OF SUPERPOSITION OF TWO PHOTOGRAPHIC PLATES.

By F. Henroteau.

When we try to superpose two plates of star fields having common regions, we obtain a strange figure which seems to indicate a distribution in concentric circles or spirals. A slight shift of one photograph with respect to the other makes the common center of these spirals move a great amount.

We will have a much simpler case if we consider two identical star

fields or representations, but the second one turned through a certain small angle ω, with respect to the first. The apparent spirals will then become apparent concentric circles, and it is easy to prove that for a certain linear displacement b of one plate with respect to the other, the apparent displacement of the center will be $a = b \operatorname{cosec} \omega/2$ and if ω is small one can see that a is considerably larger than b. Also the direction of a is nearly perpendicular to the direction of b.

An apparatus based on the above principle of the superposition of two star plates could be used for measuring small displacements b by measuring a. It might perhaps assist greatly in measuring radial velocities, parallaxes, and other small distances encountered in astronomy, physics, or engineering.

A more detailed description of the above effect will be given together with photographs in the *Journal of the Royal Astronomical Society of Canada.*

A REGION OF THE SKY RICH IN VARIABLE STARS.

By F. Henroteau.

A region of the Milky Way in Delphinus is worthy of being mentioned as containing a large number of variable stars of long period or irregular. The cause of their variation is probably the same for all and seems probably to be looked for in the presence of enormous clouds of nebulous material. In the above region of only a few square degrees we might mention as already known the following variables (irregular or of long period):

Star	α 1855.0			δ 1855.0	
	h	m	s	°	′
RS Delphini	20	22	28	+15	47.6
RT Delphini	20	22	30	+15	46.9
Y Delphini	20	34	44	+11	21.8
S Delphini	20	36	24	+16	34.2
T Delphini	20	38	38	+15	52.4
U Delphini	20	38	50	+17	34.0
V Delphini	20	41	11	+18	48.3
X Delphini	20	48	13	+17	5.6
TZ Pegasi	21	2	11	+15	37.2

Most likely a search in the above region would reveal more variables and certainly a study of all the light-curves of such a group of variables is greatly to be desired.

A GRAPHICAL CONSTRUCTION FOR OBTAINING THE PERIOD OF A PHENOMENON.

By F. Henroteau.

The following construction gives the least positive residues of given numbers t_1, t_2 . . . for divisor P; using only measurements within a small compass, t_1, t_2 . . . may be given times and P a length of time we want to try as a period.

First, we assume P smaller than 1 or $\sqrt{10}$ or $\sqrt{100}$ or in general $\sqrt{10^n}$. If it is smaller than $\sqrt{10^n}$ we make the following construction:

1. Draw a square having the length $\sqrt{10^n}$ for its side. Let us call it $ABCD$, A being the upper left corner and A, B, C and D following each other in a counter clockwise direction. Draw the diagonals BD and AC. Through E where AC cuts BD draw a parallel to BC which cuts AB in A. Join CA, which cuts BD in E, through which we draw a parallel to BC which cuts AB in A_2. Join CA_2 and continue the construction as said in the preceding sentence but replacing the index 1 successively by 2, 3, ... It is easy to prove that $BA_1 = BA/2$, $BA_2 = BA/3$, and $BA_n = BA/(n+1)$.

2. On a straight line passing through B, we take distances BC_1, BC_2 . . . equal to $1/t_1$, $1/t_2$ . . . $1/t_n$ multiplied by 10^n. The numbers $1/t_n$ or reciprocals of t_n are easily found in a table of reciprocals such as Barlow's.

3. All the above constructions are permanent; they are the same for as many values of P as we want to try. To try a definite number P we make the following construction:

4. Place the line of reciprocals in such a way that the length $BF = \sqrt{10^n}$ (measured from B) projected upon BA be equal to P. Through C_1, C_2 . . . C_n we draw parallels to BC. Each of these lines can only cut one of the lines CA_1, CA_2, . . . CA_n within the angle ABD. Let us call K_n the point where the parallel to BC drawn through C_n cuts one of these lines. The projections from C of K_1, K_2, . . . K_n upon the parallel to BC drawn through F give all the extremities of the lengths H_1 . . . H_n, residues of t_1, t_2 . . . t_n for divisor P; counting these lengths from the side AB.

The construction which is easily demonstrated may be of value in some cases as being very compact. However, the apparent compactness of the figure is offset by the inaccuracy of construction for large values of t.

NOVA CYGNI NO. 3. PRELIMINARY RESULTS.

By F. Henroteau and J. P. Henderson.

The Nova appeared only a few days before the meeting. From several nights' observations the following results were obtained:

1. A plate (direct photograph) taken on July 20, 1920, of the region of the Nova does not show even a faint star where the Nova appeared. The faintest stars visible on this plate being about the twelfth magnitude.

2. In the spectrum of the Nova, the bright lines were very slow to appear, the Nova being discovered on August 21, 1920, the bright lines only started to appear toward the end of the night of August 25. In other novae the bright lines usually appeared on the night after the discovery or even the same night. Here the Nova passed its maximum brightness which was estimated 1.6 magnitude on August 24 before showing bright lines.

3. The radial velocity indicated by the broad absorption lines, chiefly of hydrogen, was very large (if the displacements of these lines be taken as indicating radial velocity) and increased gradually during the few first nights being when first measured of about 600 km/sec. and reached finally a little more than 1000 km/sec. The increase of velocity can be represented easily by an arc of hyperbola.

4. Even after the appearance of the bright bands in the spectrum, the wide absorption lines did not change their character and no narrow and sharp metallic lines appeared in the spectrum such as was the case for Nova Aquilae No. 3 in 1918 where they appeared in great number. The spectrum of Nova Cygni seemed to be composed of three sets of lines, first wide absorption lines indicating finally a velocity in the neighborhood of 1000 km/sec.; secondly wide absorption bands indicating a velocity in the neighborhood of zero km/sec.; in the third place fairly narrow absorption lines superposed on the emission bands and also indicating a radial velocity in the neighborhood of zero. Among the first set of lines, which indicate as in every nova investigated up to now *a velocity of approach*, were the wide absorption lines H and K of calcium, while sharp absorption lines H and K of calcium were also visible but not displaced, probably due to the presence of a cloud of calcium between the star and us.

5. The emission bands were not as broad as in the case of Nova Aquilae No. 3. In the latter the emission bands not only seemed to be divided in two by an absorption band, but this absorption band also seemed to be divided by another narrower emission band, so that in the case of Nova Aquilae most of the large emission bands appeared like triplets.

6. The visual, photographic, and photo-visual light-curves of Nova

Cygni obtained by the authors indicate a rapid decrease of light, much more rapid than in Nova Aquilae.

7. From the data obtained it seems that the absolute brightness of Nova Cygni No. 3 at maximum must have been much smaller than the absolute brightness of Nova Aquilae No. 3 at maximum. The great apparent brightness of the former in such a case would then be indicative of a much greater parallax for Nova Cygni than for Nova Aquilae.

THE SPECTROSCOPIC BINARY ν ERIDANI.

By F. Henroteau and J. P. Henderson.

Stars of the β Canis Majoris type are specially interesting because they appear to be very short period binaries performing a whole revolution in a fraction of a day. They all have early class B spectra the lines of which seem sometimes to vary in appearance, also the range of apparent radial velocity changes, and the factor $a \sin i$ is small. The character of these indicates great complexity of action in the stars themselves and suggests disturbances such as might be expected in great nebulous clouds around a nucleus of condensation—possibly the early stages in the evolution of binary stars. If B class stars mark the first stage of evolution it might be necessary to continue the investigation into the giant class A, then giant class F and G and so on to bring the theory of evolution into agreement with Russell's theory. Thus if pulsation of any sort is present in a giant star such as all Cepheids apparently are it indicates a binary in formation.

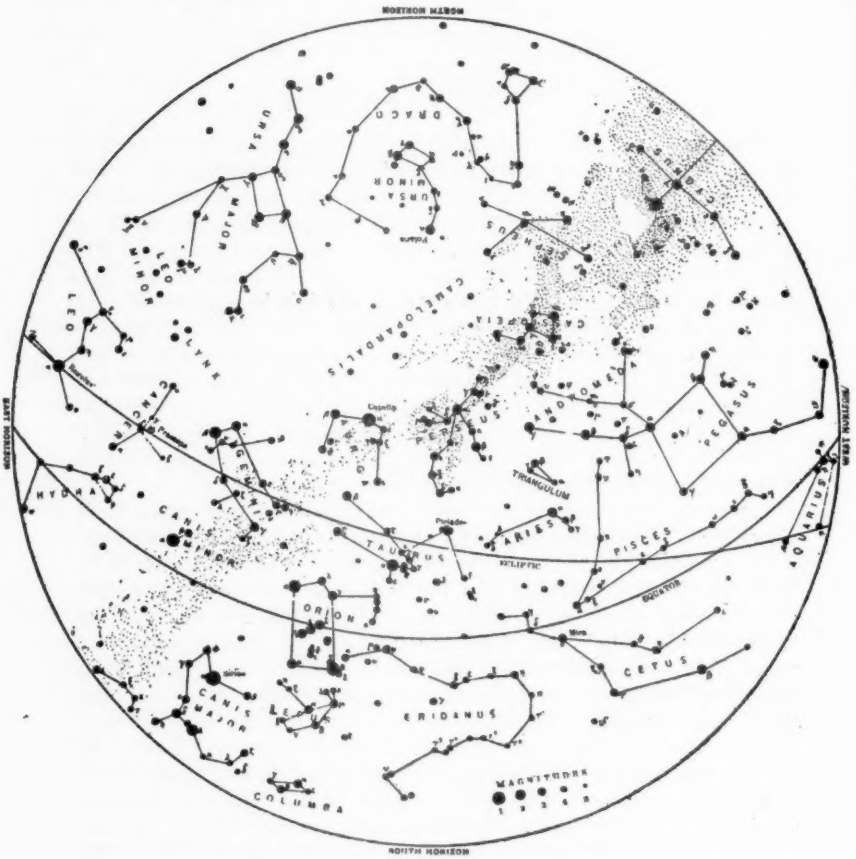
It was decided to search for any short period binaries among early class B stars by taking successive exposures during the same night. Thus ν Eridani was found and the period determined roughly as $0^d.29$. With the aid of many more velocities extending over a period of more than 18 years kindly supplied by other observatories it was fixed at $0^d.28516$ which fitted most of the observations very closely and gave a curve indicating eccentricity about zero. Considering variations in range and irregularities previously found in the other stars of similar type it may be possible that the discordances from the curve as indicated by some of the observations are real and that this star also may be irregular, but most of the observations may have occurred on a section of a larger curve when the center of mass of this binary system was moving uniformly while the discordant ones occurred when it was not —thus possibly we have a triple system with high eccentricity of the longer period.

(To be continued.)

PLANET NOTES FOR JANUARY, 1921.

The *moon's* phases are as follows:

New Moon	January	8 at	11:26.8 P.M.	C.S.T.
First Quarter		17 "	0:30.9 A.M.	"
Full Moon		23 "	5:07.9 P.M.	"
Last Quarter		30 "	2:02.1 "	"



THE CONSTELLATIONS AT 9:00 P. M. JANUARY 1.

Mercury will not be visible this month. It is at aphelion on the 2nd and at superior conjunction on the 16th.

Venus, *Mars*, and *Uranus* will be very close together in the sky during the entire month. At noon on the 9th, C. S. T., Mars and Uranus will be in con-

junction, with Mars only 15 minutes of arc south of Uranus. Three hours later Venus will be in conjunction with Uranus, with Venus 41 minutes of arc south of the other, and at nine o'clock that evening Venus and Mars will be in conjunction, with Venus 25 minutes of arc south of Mars. In the early evening of that day it may therefore be possible to see all three of these planets in the same telescopic field of view if a small telescope with low power eye-piece is used. Such a close approach of three planets is a comparatively rare occurrence and will be worth seeing. All three planets will be low in the southwest after sunset.

Jupiter, *Saturn*, and *Neptune* are likewise grouped in the opposite part of the sky although some degrees apart. Jupiter will be in Leo, Saturn in Virgo, and Neptune in Cancer. Throughout the month we shall be on the unilluminated side of Saturn's rings and the shadow of the rings should be seen on the planet.

Saturn.—It was cloudy at Northfield for several days before and after November 7 so that it was not possible to observe Saturn when the earth passed through the plane of Saturn's rings. It is hoped that other observers were more fortunate in their treatment by the weather man. Another opportunity will come on February 22 when the earth again passes through the plane of the rings.

Occultations Visible in the United States, January, 1921.

[NOTE:—Geographical positions are indicated by giving for each point, first the latitude, then the longitude, the two being separated by a hyphen. A line drawn on a map through the two or more points thus indicated will mark approximately the limit of the region of visibility for the United States. The time given is the approximate Greenwich time of the middle of the occultation as seen from the United States.]

Jan. 2, 0^h. 86 Virg., Mag. 5.6. North of 44°-126°, 36°-108°, 27°-91°, and west of 27°-91°, 39°-80°, 50°-71°. (Farther east, occurs after sunrise.)

Jan. 14, 13^h. 25 Pisc., Mag. 6.2. South of 38°-127°, 44°-113°, 49°-90°, 51°-68°.

Jan. 15, 17^h. 60 Pisc., Mag. 6.2. Generally south of lat. 48° and west of long. 89°.

Jan. 19, 14^h. 85 H^1 Tauri, Mag. 6.0. South of 28°-108°, 31°-95°, 32°-76°.

Jan. 20, 19^h. 119 Tauri, Mag. 4.9. North of 49°-104°, 44°-86°, 39°-72°.

Jan. 20, 20^h. 120 Tauri, Mag. 5.6. North of 50°-104°, 45°-89°, 40°-72°.

Jan. 21, 22^h. 26 Gem., Mag. 5.2. Northeast of 42°-125°, 36°-110°, 30°-95°, 24°-78°.

Jan. 23, 15^h. 84 B. Cancri, Mag. 6.4. Throughout the U. S.

Jan. 23, 19^h. A^1 Cancri, Mag. 5.5. Throughout the U. S., except northeast of 44°-78°, 40°-70°.

Jan. 23, 21^h. A^2 Cancri, Mag. 5.7. Throughout the U. S.

Jan. 24, 1^h. 60 Cancri, Mag. 5.7. South of 50°-119°, 45°-107°, 40°-92°, and west of 40°-92°, 34°-92°, 28°-94°.

Jan. 24, 13^h. *h* Leonis, Mag. 5.2. South of 30°-96°, 31°-81°.

Jan. 26, 19^h. *v* Leonis, Mag. 4.5. South of 34°-123°, 32°-110°, 28°-96°.

Jan. 30, 20^h. *p* Librae, Mag. 5.3 East of 30°-116°, 36°-113°, 42°-106°, and south of 42°-106°, 37°-93°, 32°-79°.

Jan. 30, 21^h. 22 Librae, Mag. 6.5. East of 50°-112°, 40°-117°, 30°-117° (except Maine.)

ARTHUR SNOW,
Ass't. Nautical Almanac Office, U. S. Naval Observatory.

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, September 20 to October 20, 1920.

The present is one of the largest reports that the Association has ever made, and may be attributed partly to the interest aroused by Nova Cygni, and partly to the unusually good weather conditions which seem to have been general. The Nova has apparently not fluctuated after the manner of recent novae, but has diminished with great rapidity, and it is very important that it should be observed as long as it is visible. Also attention is called to SS Aurigae, 060547, and U Geminorum, 074922, which are very irregular stars. M. Lachini was the only observer to note the maximum of the former on J. D. 2574. An error has been noted on the chart of W Persei, 024356, in that the comparison star designated 9.9 is of magnitude 9.1, and it is important that all who have this star on their list should note this correction.

The annual meeting of the Association was held at Cambridge, Mass., Nov. 6, with 77 members present and 70 at the dinner at which Mr. MacMillan, the Arctic explorer, was a guest of honor. A full report of this meeting, prepared by Mr. G. C. Waldo, Jr., appears elsewhere in this issue.

Professor H. H. Turner, of Oxford, England, was elected the twelfth Honorary Member of the Association, and Mr. W. T. Olcott and Professor S. A. Mitchell were made Patrons. The Pickering Club of the Soldan High School, of St. Louis, Mo., has been granted a Life Membership; and the following were elected to active membership:

J. Q. Adams, Chicago, Ill.
W. W. Bickell, Brookline, Mass.
M. Elbeck Nielson, Brookline, Mass.
Mrs. W. T. Olcott, Norwich, Conn.
K. O. Reesinck, Amsterdam, Holland.
Arthur L. Truesdell, Leverett, Mass.
R. L. Williams, Fayetteville, N. Y.

This brings the total membership to 220.

The following nominating committee has been appointed by the President: Miss Margaret Harwood, chairman, Dr. Charles A. Godfrey, and Mr. George C. Waldo. The kind invitation of Dr. Caroline E. Furness to hold the spring meeting at Vassar College Observatory was accepted.

Hereafter the distribution of charts is to be in the hands of Mr. Arthur C. Perry, 277 Broadway, New York. All those who desire additional chart equipment should communicate with him. The Association has decided to coöperate with Professor C. P. Olivier, McCormick Observatory, University of Virginia, in the observation of telescopic meteors, and observers are urged to secure additional information from him.

We welcome observations this month from the following new observers: Mr. Gerold Merton, Woldingham, England, and Mrs. Madeline Norcross, of fNantucket, Mass. Mrs. Morris resumes observation with this report. The following observers contributed to this report: Messrs. Bancroft, "Ba," Barns "Bs," Bemporad "Bp," Benini "Be," Bouton "B," Bunch "Bh," Carr "Ca," Chandra "Ch,"

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920.

September 0 = J. D. 2422568 October 0 = J. D. 2422598

001032 S Sculpt. 2601.6 8.0 Ba.

001046 X Androm. 2531.7 *13.0* Ba, 2601.6 13.2 Ba, 2603.5 *12.5* Pi.

001620 T Ceti 2574.6 6.6 L, 2583.6 6.5 L.

001726 T Androm. 2545.2 *11.0* Ch, 2601.6 13.7 Ba.

001755 T Cassiop. 2533.6 11.7 Ba, 2573.9 10.4 Ml, 2577.3 10.3 Gi, 2579.9 11.9 L_4, 2586.7 9.6 B, 2587.7 11.5 Bs_2, 2593.6 10.2 L, 2596.5 9.5 Gi, 2601.6 9.6 Ba, 2603.5 9.9 Pi, 2605.5 9.9 O, 2611.6 9.1 B, 2612.6 9.8 M.

001838 R Androm. 2545.2 *11.0* Ch, 2581.4 *12.4* Pe, 2601.6 11.8 B, 2601.6 *11.0* Wl, 2603.5 11.9 Pi, 2604.6 *11.0* V, 2608.6 *9.7* Jd, 2609.6 13.4 B, 2611.5 12.5 Pt, 2611.6 12.0 Gd, 2612.6 12.5 Hu, 2612.6 *11.0* Wl, 2614.6 *12.0* M.

001909 S Ceti 2544.4 *11.5* Ch, 2601.6 *13.7* Ba.

003179 Y Cephei 2533.6 10.2 Ba, 2585.6 12.8 B, 2609.6 13.3 B.

004047 U Cassiop. 2531.7 12.5 Ba, 2603.6 *12.8* Y.

004132 RW Androm. 2603.6 *13.1* Pi.

004746a RV Cassiop. 2610.6 *14.1* B.

004958 W Cassiop. 2533.6 10.9 Ba, 2580.4 9.0 Gi, 2589.5 9.6 O, 2596.5 9.0 Gi, 2599.5 8.9 B, 2600.5 9.2 K, 2601.6 9.9 Pt, 2601.6 9.0 Ba, 2603.5 9.7 Pi, 2607.5 9.8 O, 2612.5 9.3 Gd_2, 2612.6 9.5 Hu, 2614.6 9.8 M, 2615.5 9.4 O.

010102 Z Ceti 2601.6 9.0 Ba, 2612.6 9.1 Pi.

010940 U Androm. 2531.7 9.5 Ba, 2571.8 10.9 Ml, 2601.6 11.7 Ba, 2607.6 11.9 B, 2608.5 11.9 K, 2614.6 12.2 M.

011041 UZ Androm. 2531.7 11.0 Ba, 2601.6 13.0 Ba, 2607.6 12.5 B.

011208 S Piscium 2601.6 13.0 Ba, 2611.5 12.5 Y, 2612.6 12.4 Pi.

011272 S Cassiop. 2533.6 9.5 Ba, 2585.5 11.8 B, 2601.6 12.0 Pt, 2601.6 11.9 Ba, 2607.6 12.0 B, 2608.7 12.2 Pi, 2614.6 12.5 M.

011712 U Piscium 2601.6 11.0 Ba, 2611.6 10.9 Pt.

012350 RZ Persei 2603.5 *12.6* Pi, 2603.6 12.8 Y, 2609.6 13.5 B.

012502 R Piscium 2588.8 9.4 Pt, 2601.7 9.9 Ba, 2611.5 10.6 Y, 2611.6 10.8 Gd, 2612.6 12.0 Wl, 2612.6 11.0 Pi, 2614.6 10.6 M.

013238 RU Androm. 2531.7 *13.0* Ba, 2575.5 *12.6* Pe, 2601.7 12.2 Ba, 2603.5 12.3 Pi, 2611.6 *13.3* B, 2614.6 12.0 M.

013338 Y Androm. 2531.7 10.0 Ba, 2545.2 9.8 Ch, 2574.4 10.6 Pe, 2575.3 10.6 Pe, 2589.6 11.0 O, 2601.6 11.6 Pt, 2601.7 11.5 Ba, 2603.5 12.0 Pi, 2609.6 12.7 B, 2614.6 *12.0* M.

014958 X Cassiop. 2603.5 12.3 Pi, 2603.6 12.5 Y, 2607.6 10.6 B, 2611.6 *12.3* M.

015354 U Persei 2586.7 9.7 Pt, 2586.8 10.5 Bs, 2598.6 9.4 B, 2601.7 9.8 Ba, 2603.5 10.0 Pi, 2608.6 9.8 O, 2612.6 9.5 Hu, 2614.6 9.8 M.

021024 R Arietis 2574.6 10.3 L, 2576.3 10.4 Pe, 2583.6 10.1 L, 2593.6 9.3 Ca, 2601.5 9.1 O, 2601.7 9.0 Ba, 2601.7 8.6 Ca, 2602.6 9.1 Pt, 2603.5 9.4 Pi, 2604.6 9.2 Wl, 2607.6 8.8 B, 2608.6 9.0 O, 2612.6 9.1 Wl, 2612.6 8.8 Pi, 2614.6 9.0 M, 2615.5 8.9 O, 2615.6 9.0 Wl.

021143a W Androm. 2573.5 8.1 Gi, 2589.6 8.8 O, 2601.5 9.2 O, 2601.7 8.5 Ba, 2603.6 9.2 Pi, 2605.5 9.2 O, 2607.6 8.7 B, 2614.6 9.4 M.

021281 Z Cephei 2531.7 *13.5* Ba, 2604.6 11.3 V, 2615.5 10.4 M.

021403 o Ceti 2522.6 3.2 Bp, 2544.4 3.7 Ch, 2551.6 4.4 Bp_3, 2560.5 4.7 Bp, 2574.0 5.3 Bp_4, 2574.6 4.8 L, 2579.2 5.5 Pe_3, 2579.6 5.7 Bp_5, 2580.6 5.4 L_6, 2583.8 6.3 Ca, 2587.7 6.3 Ca, 2587.9 6.2 Wl, 2588.8 6.1 Pt, 2588.9 6.3 Bp_7, 2593.7 6.1 L, 2596.4 6.7 Bp,

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

021403 o Ceti	2599.7 6.9 Bh, 2601.7 6.3 Ba, 2608.7 6.7 Ca, 2610.9 7.5 Wl, 2612.6 7.3 Pi, 2614.6 7.2 M.
021558 S Persei	2600.6 10.9 B, 2603.6 11.3 Pi, 2603.6 10.7 O, 2614.6 10.5 M.
022150 RR Persei	2531.7 *13.5* Ba, 2605.5 *13.5* Y.
022813 U Ceti	2544.4 *10.5* Ch, 2612.6 9.1 Pi.
022980 RR Cephei	2531.7 12.7 Ba, 2615.5 12.0 M.
023133 R Trianguli	2573.9 7.5 Ml, 2590.8 8.2 Bs, 2601.6 9.0 Pt, 2603.6 9.0 Pi, 2603.6 8.9 O, 2607.6 8.7 B, 2608.6 9.2 O, 2614.6 9.2 M.
024356 W Persei	2590.5 9.7 Wl, 2590.5 9.7 Gd, 2593.6 9.2 Ca, 2599.5 9.2 Gd, 2603.6 9.6 Pt, 2603.6 9.5 Pi, 2603.6 9.4 O, 2606.5 9.7 Cl, 2606.6 9.1 Ca, 2614.5 9.7 Gd, 2614.6 9.0 M, 2615.5 9.7 Wl, 2615.5 9.7 O.
031401 X Ceti	2580.6 9.3 L, 2586.7 9.1 Pt, 2614.7 10.4 M.
032043 Y Persei	2574.4 10.1 Pe, 2580.4 9.7 Pe, 2586.7 9.5 Pt, 2605.5 10.1 Cl, 2608.6 10.0 O, 2614.7 9.8 M.
032335 R Persei	2578.4 13.6 Gi.
032443 Nova Persei 2	2575.4 *12.8* Pe, 2583.4 13.2 Pe.
033362 U Camelop.	2614.7 8.0 M.
041619 T Tauri	2614.7 8.7 M.
042209 R Tauri	2605.7 10.0 Pt, 2614.7 9.3 M.
042215 W Tauri	2586.7 10.3 Pt, 2592.8 10.6 M, 2605.8 11.1 V, 2607.7 11.0 Pi, 2609.7 11.0 B, 2614.7 11.5 M.
042309 S Tauri	2592.8 *12.5* M.
043065 T Camelop.	2570.3 9.9 L, 2583.6 10.8 L, 2590.8 11.2 Bs, 2601.7 11.6 Bs, 2608.7 12.0 Pi.
043208 RX Tauri	2592.8 11.4 M, 2609.7 11.8 B.
043274 X Camelop.	2590.8 10.4 Bs, 2602.6 11.4 Pt, 2603.6 11.0 O, 2605.5 10.8 O, 2605.5 10.8 Y, 2605.8 10.7 Bs, 2608.6 10.4 O, 2608.7 10.4 Pi, 2613.5 10.2 O, 2614.7 10.4 M.
044617 V Tauri	2607.7 12.4 Pi, 2612.7 12.2 B, 2614.7 *12.0* M.
045514 R Leporis	2544.4 8.0 Ch, 2570.6 8.3 L, 2581.6 7.8 L, 2587.9 9.2 Wl, 2598.7 9.1 L, 2606.8 8.5 Pt, 2608.8 8.5 Ca, 2610.9 9.5 Wl.
050022 T Leporis	2589.8 12.0 Pt.
050953 R Aurigae	2586.7 12.3 Pt, 2592.8 11.3 M.
052034 S Aurigae	2580.1 10.4 L_2, 2592.8 9.8 M, 2607.7 10.2 Pi, 2614.7 10.1 M.
052036 W Aurigae	2577.6 11.5 L, 2580.7 11.5 L.
053005a T Orionis	2571.6 10.4 L, 2574.6 11.0 L, 2576.6 11.5 L, 2581.6 10.4 L, 2585.6 10.2 L, 2589.8 10.3 Pt, 2592.9 10.8 Wl, 2593.7 10.1 L, 2598.7 10.4 L, 2610.9 11.3 Wl.
053068 S Camelop.	2588.8 10.7 Pt, 2608.7 10.2 Pi, 2614.7 11.0 M.
053326 RR Tauri	2614.7 10.7 M.
063631 U Aurigae	2605.8 *11.7* V, 2614.7 11.4 M.
054319 SU Tauri	2570.6 9.5 L, 2576.6 9.5 L, 2580.7 9.7 L, 2581.6 9.6 L, 2588.8 9.4 Pt, 2589.8 9.5 Pt, 2592.8 9.5 M, 2605.7 9.6 Pt, 2605.8 9.4 V, 2606.8 9.5 Pt, 2607.7 9.5 Pi, 2611.8 9.5 Pi, 2614.7 9.4 M.
054920 U Orionis	2544.4 6.0 Ch, 2570.9 8.0 Ml, 2583.9 7.2 Ca, 2587.7 7.3 Ca, 2588.8 7.5 Pt, 2592.8 7.7 M, 2593.9 8.0 Ml, 2606.7 7.6 Ca, 2607.7 8.5 Pi, 2607.9 8.8 Wl, 2614.7 8.5 M.
054974 V Camelop.	2580.4 13.4 Gi, 2605.5 13.5 Y, 2614.7 *12.2* M.
055353 Z Aurigae	2592.8 9.1 M, 2614.7 9.6 M.
060450 X Aurigae	2606.8 10.3 Pt, 2607.9 10.3 Wl, 2614.7 9.8 M.

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
060547	SS Aurigae	2574.6	11.9	L,	2574.6	11.8	L,	2575.6	12.4	L,	2576.6	13.0	L,
		2577.6	*12.4*	L,	2578.6	*12.4*	L,	2580.4	*12.4*	Pe,	2580.6	*13.0*	L,
		2581.6	*12.4*	L,	2583.6	*12.4*	L,	2584.6	*13.0*	L,	2585.6	*13.3*	L,
		2586.7	*12.4*	Pt,	2588.8	*12.6*	Pt,	2589.8	*13.0*	Pt,	2593.6	*13.3*	L,
		2598.6	*11.6*	L,	2601.7	*12.4*	Ba,	2602.6	*12.4*	Pt,	2603.6	*12.4*	Pi,
		2605.7	*13.0*	Pt,	2605.8	*11.6*	V,	2606.8	*13.0*	Pt,	2607.7	*13.0*	Pi,
		2611.6	11.4	Pt,	2611.7	11.3	B,	2612.6	11.3	Ba,	2612.6	11.6	Pi,
		2612.6	11.0	Y,	2612.7	11.6	B,	2618.7	11.8	Pt,	2614.7	*11.4*	M.
061647	V Aurigae	2614.7	9.7	M.									
063159	U Lyncis	2612.6	*12.4*	Y.									
064030	X Gemin.	2605.8	*11.8*	V.									
065111	Y Monoc.	2605.8	11.6	V.									
065208	X Monoc.	2576.6	7.8	L,	2582.7	7.6	L,	2587.9	8.1	Wl.,	2598.7	7.9	L,
		2610.9	9.3	Wl,	2614.7	10.2	M.						
065355	R Lyncis	2581.7	11.7	Gi,	2596.6	12.0	Gi,	2612.6	*11.9*	Y.			
070122a	R Gemin.	2589.8	7.5	Pt,	2608.7	7.3	Ca.						
070310	R Can. Min.	2575.6	10.8	L,	2585.6	10.4	L.						
071044	L_2 Puppis	2599.9	4.7	Bh.									
071713	V Gemin.	2611.8	10.8	Pt.									
072708	S Can.Min.	2587.9	8.6	Wl,	2589.9	9.0	Pt,	2599.9	8.8	Bh,	2610.9	9.9	Wl,
		2614.7	9.5	M.									
073508	U Can. Min.	2589.9	8.4	Pt.									
073723	S Gemin.	2605.9	*11.5*	V,	2614.7	*11.4*	M.						
074323	T Gemin.	2605.9	*11.2*	V.									
074922	U Gemin.	2570.6	*11.4*	L,	2571.6	*10.0*	L,	2572.6	*11.7*	L,	2574.6	*10.9*	L,
		2575.6	*10.0*	L,	2576.6	*12.3*	L,	2577.6	*12.3*	L,	2578.6	*11.7*	L,
		2579.6	*11.7*	L,	2580.6	*12.3*	L,	2581.6	*12.3*	L,	2582.6	*12.3*	L,
		2583.6	*12.3*	L,	2584.6	*12.4*	L,	2585.6	*13.3*	L,	2589.8	*12.4*	Pt,
		2593.6	*13.3*	L,	2598.6	*10.9*	L,	2605.9	9.2	V,	2606.8	9.5	Pt,
		2611.8	12.6	Pt,	2614.7	*12.4*	M.						
081617	V Cancri	2606.8	9.4	Pt.									
082405	RT Hydrae	2583.7	8.0	L.									
083019	U Cancri	2605.9	*11.3*	V.									
085008	T Hydrae	2611.8	8.1	Pt.									
085120	T Cancri	2576.6	8.7	L,	2598.7	8.7	L.						
090425	W Cancri	2582.6	10.3	L,	2598.6	8.4	L,	2605.9	8.2	V.			
093178	Y Draconis	2605.5	10.1	Y,	2612.5	9.8	Ba.						
093934	R Leo. Min.	2571.6	*10.0*	L,	2585.6	*12.3*	L.						
094211	R Leonis	2606.8	9.5	Pt.									
103769	R Urs. Maj.	2531.6	13.0	Ba,	2571.6	*10.5*	Ca,	2587.6	*10.5*	Ca,	2592.7	*11.5*	Bs,
		2601.5	12.3	Ba,	2602.5	*10.5*	Ca,	2602.6	*10.5*	Bh,	2615.5	*9.8*	Ya.
115919	R Comae B.	2531.6	9.3	Ba.									
122532	T Canum Ven.	2531.6	10.5	Ba,	2585.7	*11.5*	Bs,	2586.8	12.0	Bs.			
123160	T Urs. Maj.	2531.6	8.1	Ba,	2541.1	8.2	Ch,	2563.6	8.5	Ba,	2570.6	8.6	Ca,
		2574.3	8.9	Pe,	2581.3	9.0	Pe,	2587.6	9.6	Ca,	2587.6	9.2	Wl,
		2597.2	10.2	Pe,	2598.5	10.0	Gd,	2600.6	10.5	Wl,	2600.6	9.9	Pt,
		2601.5	10.2	Ba,	2602.5	9.8	Ca,	2603.5	*9.8*	Jd,	2606.5	*10.1*	Jd,
		2608.5	*10.8*	Jd,	2608.5	10.4	K,	2612.5	10.5	Ba.			
123459	RS Urs. Maj.	2531.6	*13.7*	Ba,	2574.3	*12.6*	Pe,	2581.3	12.9	Pe,	2587.6	10.4	Ca,
		2601.5	*12.0*	Ba,	2604.5	10.4	Ca,	2608.5	*11.0*	K.			
123961	S Urs. Maj.	2531.6	10.0	Ba,	2541.1	10.8	Ch,	2563.6	11.3	Ba,	2572.4	11.6	L,
		2574.3	11.5	Pe,	2580.3	11.4	L,	2587.6	11.2	Wl,	2600.6	10.3	Wl,
		2600.6	10.4	Pt,	2601.5	10.1	Ba,	2602.5	9.5	Ca,	2603.5	9.7	Jd,
		2608.5	10.0	Jd,	2608.5	10.0	K,	2612.5	8.7	Ba.			

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number Name	J.D. Est. Obs. J.D. Est. Obs. J.D. Est. Obs. J.D. Est. Obs.
132422 R Hydrae	2537.1 7.3 Ch.
133273 T Urs. Min.	2531.6 *13.2* Ba, 2603.5 *11.4* V, 2612.5 10.8 Ba.
134440 R Can. Ven.	2531.6 8.0 Ba, 2586.8 8.2 Bs, 2600.5 10.6 Pt, 2611.5 10.4 Y, 2612.5 10.6 Pi.
140113 Z Bootis	2531.6 9.0 Ba, 2605.5 10.6 Y.
141567 U Urs. Min.	2531.6 7.9 Ba, 2586.6 10.2 B, 2587.5 10.7 Ro_5, 2588.8 10.7 Pt, 2589.5 10.7 O, 2600.5 10.7 Ro_5, 2608.6 10.9 Pi, 2609.5 10.9 Ro_5, 2612.5 11.1 Ba.
141954 S Bootis	2531.6 11.4 Ba, 2575.3 *12.5* L, 2578.3 12.8 Gi, 2580.3 *12.9* L, 2605.5 *12.0* Pi, 2608.5 *12.0* K, 2612.5 *12.0* Ba.
142539 V Bootis	2531.6 11.1 Ba, 2571.6 8.4 Ca, 2575.3 8.4 L, 2582.3 7.6 Pe_2, 2587.5 7.8 Gd, 2587.5 7.6 Wl, 2587.6 7.7 Ca, 2593.6 7.5 Ca, 2600.1 7.5 Bh_2, 2600.5 7.5 Pt, 2600.5 7.5 Gd, 2601.5 7.3 Wl, 2602.5 7.5 Ca, 2605.5 7.4 Su, 2605.5 7.7 K, 2605.5 7.2 Pi, 2608.5 7.6 Wl, 2610.5 7.5 Ca, 2612.5 7.1 Ba, 2614.5 8.0 M.
142584 R Camel.	2531.6 *12.7* Ba, 2578.4 10.4 Gi, 2596.6 9.9 Gi, 2600.5 9.8 O, 2608.7 9.6 Pi, 2610.5 9.4 O_2, 2612.5 8.9 Ba.
143227 R Bootis	2531.6 11.1 Ba, 2574.3 8.5 Pe, 2581.8 8.5 Pe_2, 2588.3 8.9 Bs_2, 2592.5 8.0 Wl, 2599.6 8.3 Bh, 2601.5 7.4 Wl, 2604.5 7.6 Pt, 2605.5 6.4 Su, 2605.6 8.2 Bh, 2608.5 7.8 Ya, 2609.5 7.8 Wl, 2614.5 8.0 M.
144918 U Bootis	2531.6 10.3 Ba, 2569.3 11.0 Gi, 2583.3 11.8 Gi.
151520 S Librae	2547.1 10.0 Ch, 2570.3 9.6 L.
151714 S Serpentis	2531.6 7.8 Ba, 2580.3 8.9 L.
151731 S Cor. Bor.	2531.6 12.7 Ba, 2545.1 10.9 Ch, 2602.6 12.4 Pt, 2604.5 12.4 Y, 2605.5 12.9 B, 2609.5 12.5 M.
151822 RS Librae	2570.3 9.9 L.
152714 RU Librae	2570.3 7.4 L, 2578.6 7.8 L_2, 2593.3 8.2 L.
153378 S Urs. Min.	2531.6 8.7 Ba, 2570.7 8.1 Ca, 2570.7 8.4 Ml, 2572.3 9.2 Pe_2, 2579.3 9.2 Pe, 2587.5 8.3 Ro, 2591.5 8.4 Wl, 2591.7 8.1 Bs_2, 2593.6 8.1 Ca, 2600.6 8.2 Wl, 2601.1 8.2 Ro_5, 2602.5 8.0 Ca, 2602.6 8.1 Pt, 2603.5 8.3 V, 2603.6 8.9 Bh, 2604.8 7.6 Bs, 2605.5 8.4 K, 2605.5 8.1 O, 2608.5 8.4 Wl, 2608.6 8.2 Jd, 2608.6 8.4 Pi, 2608.9 8.3 Ro_5, 2610.6 8.0 Ca, 2612.5 8.1 Ba, 2612.6 8.3 Su, 2614.5 8.1 M, 2615.5 8.2 Ya.
154428 R Cor. Bor.	2531.6 6.2 Ba, 2533.6 6.4 Ba, 2541.1 6.4 Ch, 2541.6 5.8 My, 2544.6 5.8 My, 2545.6 5.9 My, 2547.1 6.5 Ch, 2549.65.8 My, 2550.6 5.9 My, 2552.6 5.9 My, 2556.6 6.0 My, 2557.6 6.1 My, 2560.6 6.2 My, 2562.6 6.3 My, 2563.5 6.3 Ba, 2564.6 6.2 My, 2570.6 6.0 Ba, 2570.6 6.4 Ca, 2571.3 6.3 L, 2571.3 6.4 Be, 2571.6 6.4 Ca, 2572.3 6.4 Be, 2572.4 6.2 L, 2573.3 6.1 L, 2573.4 6.4 Gi, 2574.4 6.4 Pe, 2575.3 6.1 Be, 2575.3 6.1 L, 2576.3 6.1 L, 2576.3 6.4 Pe, 2578.3 6.1 L, 2579.3 6.4 Gi, 2580.3 6.2 L, 2580.3 6.2 Be, 2581.3 6.2 Pe, 2583.3 6.1 L, 2583.7 6.4 Mu, 2584.7 6.0 Bs, 2585.7 6.3 Mu, 2586.6 6.0 Bh, 2587.5 6.6 K, 2587.5 6.3 Ya, 2587.6 6.6 Wl, 2587.6 6.3 Ca, 2587.6 6.2 O, 2588.5 6.5 Ro, 2588.7 6.4 Mu, 2589.5 6.3 Ca, 2589.5 6.2 O, 2591.3 6.2 L, 2592.5 6.0 Ba, 2594.3 6.1 L, 2594.5 6.3 Ca, 2594.5 5.9 Cl, 2594 8 5.8 Bs, 2596.3 6.1 L, 2596.4 6.4 Gi, 2596.5 6.3 Ca, 2598.3 6.1 L, 2598.5 6.0 Gd, 2598.5 6.0 Hn, 2598.6 6.0 Bh, 2599.6 6.0 Pt, 2599.6 6.0 Bh, 2599.7 6.3 Mu, 2600.5 6.1 O, 2600.5 6.0 Pi, 2600.5 6.4 K, 2600.5 6.3 Ro, 2600.6 5.5 Su, 2600 7 6.4 Mu, 2601.5 5.9 Ba, 2601.5 6.3 Ro, 2601.6 6.1 Wl, 2601.6 5.8 Bh, 2601.6 6.4 M, 2601.7 5.9 Bs, 2602.5 6.1 Ca, 2602.6 5.9 Bh, 2602.6 5.4 Su, 2602.6 6.0 Pt, 2602.6 6.3 Mu, 2603.5 6.5 Jd, 2603.5 6.5 Hn, 2603.5 6.4 V, 2603.6 6.0 Bh, 2604.5 6.1 Ca, 2604.6 6.0 Bh,

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
154428	R Cor. Bor.	2605.5	6.1	O,	2605.5	6.4	K,	2605.5	6.0	Pi,	2605.6	6.0	Bh,
		2606.5	6.5	Cl,	2606.5	6.1	Ca,	2606.5	6.5	Ro,	2607.5	6.2	Mo,
		2607.5	6.2	O,	2607.7	6.3	Mu,	2608.5	6.1	Ca,	2608.5	6.4	Cl,
		2608.5	6.3	K,	2608.6	6.4	Wl,	2608.6	6.0	Bh,	2608.7	5.8	Bs,
		2609.5	6.3	Cl,	2609.5	6.5	Ro,	2609.5	6.4	M,	2609.6	6.1	Bh,
		2610.5	6.1	Ca,	2610.5	6.0	Pt,	2610.6	5.9	Bh,	2610.6	6.5	Mu,
		2612.5	6.0	Pi,	2612.5	6.3	Ba,	2613.5	6.2	O,	2614.5	5.2	Su,
		2615.5	6.2	O.									
154536	X Cor. Bor.	2531.6	12.3	Ba,	2609.5	*12.5*	M.						
154615	R Serpentis	2531.6	11.6	Ba,	2576.3	*11.6*	Pe,	2605.6	*11.6*	Pi.			
154639	V Cor. Bor.	2531.6	9.3	Ba,	2587.6	9.9	Gd,	2598.5	8.1	Gd,	2600.5	8.1	B,
		2600.6	8.6	Pt,	2605.5	8.8	Pi,	2608.5	8.3	Ya,	2609.5	8.7	M.
155229	Z Cor. Bor.	2531.6	*13.5*	Ba.									
155526	T Cor. Bor.	2576.3	9.2	Pe,	2577.3	9.1	Pe.						
160118	R Herculis	2600.5	11.9	B,	2601.5	12.1	Ba,	2601.6	11.8	Ya,	2605.5	*10.7*	Pi.
160210	U Serpentis	2533.6	10.6	Ba,	2570.7	8.4	Ml,	2585.7	9.8	Bs,	2589.7	8.8	Bs,
		2601.5	8.7	Ba,	2601.6	8.8	Pt,	2605.5	8.8	Y,	2605.5	8.8	K,
		2609.5	8.8	M,	2612.5	9.4	Pi.						
160221	X Scorpii	2576.3	11.5	L.									
160625	RU Herculis	2533.6	8.2	Ba,	2580.3	10.7	Pe,	2586.6	9.6	B,	2601.6	10.5	Pt,
		2601.6	10.5	Ya,	2605.5	10.6	O,	2609.5	10.3	M,	2612.5	10.7	Ba.
		2612.5	11.0	Pi.									
161138	W Cor. Bor.	2533.6	9.4	Ba,	2604.5	12.0	Y,	2605.5	12.0	Pi,	2609.5	*11.5*	M,
		2612.5	*12.0*	Ba.									
161607	W Ophiuchi	2570.6	12.3	Ba,	2608.5	12.8	B.						
162119	U Herculis	2545.1	*11.0*	Ch,	2578.4	10.9	Gi,	2587.6	*10.9*	Ca,	2599.6	10.8	Bh,
		2599.6	10.8	Hu,	2601.5	11.1	Ba,	2601.5	10.7	V,	2604.8	9.6	Bs,
		2605.5	10.9	O,	2605.6	10.5	Bh,	2607.5	10.6	Gd,	2607.5	10.6	Pi,
		2611.5	10.7	Pt,	2611.5	10.6	M.						
162319	Y Scorpii	2571.3	12.1	Gi,	2580.3	11.5	Gi.						
162807	SS Herculis	2533.6	10.0	Ba,	2563.6	8.6	Ba,	2570.6	8.8	Ba,	2580.4	10.4	Pe,
		2583.3	10.0	Pe,	2586.6	10.0	B,	2601.5	11.7	Ba,	2607.5	12.0	Gd,
		2612.5	12.2	Ba.									
163137	W Herculis	2545.1	*11.0*	Ch,	2600.5	8.7	B,	2601.6	8.8	V,	2602.6	8.7	Pt,
		2604.5	9.1	Y,	2606.5	8.6	Pi_2,	2609.5	8.4	M,	2612.5	8.4	Ba.
163172	R Urs. Min.	2531.6	9.5	Ba,	2586.6	9.1	B,	2609.5	9.8	M,	2611.6	9.0	Ba.
163266	R Draconis	2531.6	11.8	Ba,	2544.1	*11.0*	Ch,	2584.7	*11.5*	Bs,	2594.6	*12.0*	Wl,
		2604.6	11.8	Y,	2608.5	11.5	B,	2608.6	*12.0*	Wl,	2608.7	12.0	Pi,
		2609.5	11.4	M,	2611.6	11.5	Ba.						
164055	S Draconis	2583.3	7.8	Pe,	2605.5	9.0	Pi,	2609.5	9.3	M,	2611.6	8.9	Ba.
164715	S Herculis	2533.6	9.2	Ba,	2569.3	10.5	Gi,	2581.4	10.6	Pe,	2583.3	10.7	Gi,
		2599.6	11.4	B,	2601.5	11.5	Ya,	2607.5	11.2	Pi,	2611.5	11.5	M,
		2612.6	12.0	Ba.									
165202	SS Ophiuchi	2601.5	11.8	Ba.									
165631	RV Herculis	2533.6	12.6	Ba,	2587.6	10.1	O,	2599.5	11.2	Gd,	2599.6	11.0	B,
		2600.6	11.3	Pt,	2601.5	11.5	Ya,	2601.5	11.4	Ba,	2601.6	11.5	M,
		2605.5	11.5	O,	2607.5	11.6	Pi.						
170215	R Ophiuchi	2557.1	10.2	Ch,	2570.6	11.8	Ba,	2588.7	*11.5*	Bs,	2598.5	*9.8*	Hn,
		2609.5	*11.0*	Wl.									
170627	RT Herculis	2533.6	11.9	Ba,	2607.5	*12.4*	Pi.						
171401	Z Ophiuchi	2569.4	11.8	Gi,	2583.3	12.1	Gi,	2601.5	12.0	Ba,	2601.6	*11.0*	V,
		2602.6	11.9	Pt,	2605.5	11.7	B.						
171723	RS Herculis	2533.6	7.9	Ba,	2570.7	9.0	Ml,	2577.3	9.6	Pe,	2580.3	9.9	Pe,
		2586.6	10.2	B,	2587.6	10.4	O,	2599.5	11.3	Gd,	2599.6	11.5	Hu,
		2600.5	*11.0*	K,	2600.6	11.5	Pt,	2600.6	11.2	Hl,	2601.6	11.4	Ya,
		2607.6	12.0	Pi,	2611.5	12.3	M,	2612.6	12.4	Ba.			

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
172809	RU Ophiuchi	2533.6	*12.0*	Ba,	2599.6	10.3	B,	2601.5	10.8	Ba,	2601.6	10.0	Pt,
		2611.5	9.5	M.									
173557	TY Draconis	2582.3	8.9	Pe.									
175111	RT Ophiuchi	2599.6	9.2	B,	2601.5	9.4	Ba,	2601.6	10.0	Pt,	2607.6	10.8	Pi,
		2615.5	10.0	M.									
175458a	T Draconis	2577.5	11.4	Gi,	2604.6	11.8	Y,	2605.5	10.6	Pi,	2608.6	11.3	B,
		2611.5	10.8	Gd.									
175458b	UY Draconis	2604.6	10.6	Y.									
175519	RY Herculis	2546.2	*11.7*	Ch,	2574.4	*12.1*	Pe,	2599.6	11.5	B,	2599.6	11.4	Hu,
		2601.5	10.8	Ba,	2601.6	11.6	Pt,	2607.6	10.8	Pi,	2611.5	10.2	M.
175654	V Draconis	2531.7	11.6	Ba.									
180531	T Herculis	2533.6	7.1	Ba,	2544.1	7.6	Ch,	2557.1	8.2	Ch,	2570.6	9.3	Ca,
		2571.3	9.4	L,	2574.4	9.7	Pe,	2580.8	10.8	L_2,	2584.6	10.5	B,
		2587.6	*11.0*	Ca,	2589.7	12.6	Bs,	2599.6	12.0	Hu,	2600.6	*11.6*	Ya,
		2600.6	12.1	Pt,	2602.5	*11.0*	Ca,	2603.6	*11.0*	V,	2607.5	11.6	Gd,
		2607.6	12.2	Pi,	2609.5	12.5	B,	2611.5	12.0	M,	2612.6	13.1	Ba.
180565	W Draconis	2531.7	*13.0*	Ba,	2608.7	*11.8*	Pi,	2612.6	*12.5*	Ba.			
180666	X Draconis	2531.7	11.7	Ba,	2608.7	11.0	Pi,	2612.6	12.2	Ba.			
180911	Nova Ophiu.4	2533.6	10.4	Ba,	2563.6	10.8	Ba,	2569.4	11.4	Gi,	2572.4	10.9	L,
		2579.3	11.0	L_2,	2579.4	11.3	Gi,	2588.6	11.2	Pt,	2596.5	10.9	Pt,
		2600.5	11.3	Pt,	2602.6	11.2	Pt,	2603.5	*11.1*	V,	2607.6	11.1	B,
		2611.5	11.3	Pt,	2612.6	11.4	B.						
181103	RY Ophiuchi	2571.3	13.4	Gi,	2583.4	13.2	Gi,	2599.6	11.1	B,	2601.5	11.5	B,
		2602.6	11.0	Pi,	2615.5	10.0	M.						
181136	W Lyrae	2533.7	10.2	Ba,	2578.4	12.0	L,	2584.7	12.5	B,	2603.6	11.5	Hu,
		2604.6	11.2	Y,	2605.5	11.5	Pi,	2605.6	11.1	B,	2611.5	10.5	Pt,
		2611.5	9.7	M,	2611.5	10.0	Gd,	2611.6	10.8	Ba.			
182224	SV Herculis	2578.4	*13.0*	L,	2580.3	*11.9*	Pe,	2612.6	*13.3*	Ba.			
182306	T Serpentis	2601.5	*13.0*	Ba.									
183149	SV Draconis	2533.7	10.4	Ba,	2605.5	13.3	Y,	2611.6	*13.0*	Ba.			
183308	X Ophiuchi	2533.7	7.3	Ba,	2571.3	8.5	L,	2583.3	8.7	L,	2586.6	8.7	B,
		2587.6	8.8	Gd,	2600.5	8.2	Gd,	2600.6	8.5	Ya,	2601.5	8.9	Ba,
		2602.6	8.5	Pi,	2607.5	9.0	O,	2611.5	8.9	M,	2611.6	8.8	B.
184134	RY Lyrae	2601.5	13.5	Ba,	2607.6	*11.7*	Pi,	2611.6	*13.3*	M.			
184205	R Scuti	2531.6	6.2	Ba,	2533.7	6.1	Ba,	2541.6	6.1	My,	2542.1	5.8	Ch,
		2544.6	6.2	My,	2545.6	6.2	My,	2549.6	6.2	My,	2552.6	6.1	My,
		2556.6	5.8	My,	2557.6	5.6	My,	2560.6	5.2	My,	2562.6	5.1	My,
		2564.6	5.0	My,	2569.3	5.2	Be,	2570.3	5.4	Be,	2570.5	5.3	Ba,
		2570.6	5.5	Ca,	2571.3	5.4	Be,	2572.3	5.4	Be,	2573.4	5.1	Gi,
		2574.3	5.6	Pe,	2575.3	5.3	L,	2575.3	5.2	Be,	2576.3	5.6	Pe,
		2576.4	5.3	Be,	2578.3	5.2	L,	2578.3	5.7	Pe,	2579.3	5.2	Gi,
		2580.3	5.3	L,	2580.3	5.3	Be,	2581.3	5.6	Pe,	2583.3	5.2	L,
		2583.7	5.1	Mu,	2585.7	5.1	Mu,	2585.8	4.8	Bs,	2586.6	5.8	Bh,
		2587.6	5.5	K,	2587.6	5.7	Ca,	2587.6	5.7	O,	2588.7	5.2	Mu,
		2589.5	5.7	O,	2589.5	5.7	Ca,	2589.7	4.6	Bs,	2591.3	5.3	L,
		2592.5	5.8	Wl,	2592.7	4.5	Bs,	2593.3	5.5	Be,	2593.6	5.7	Ca,
		2594.3	5.5	L,	2595.3	5.6	Pe,	2595.3	5.7	Gi,	2596.3	5.5	Be,
		2596.3	5.3	L,	2596.5	5.3	Pt,	2596.6	5.7	Ca,	2598.3	5.4	L,
		2598.3	5.6	Be,	2598.5	6.1	Hn,	2598.6	6.0	Bh,	2598.6	5.7	Gd,
		2599.6	5.6	Pt,	2599.6	5.8	Bh,	2599.7	5.1	Mu,	2600.5	5.8	O,
		2600.5	5.6	Ya,	2600.5	5.5	K,	2600.5	5.2	Pi,	2600.6	5.8	Su,
		2600.6	5.8	Wl,	2600.7	5.3	Mu,	2600.8	4.7	Bs,	2601.5	5.8	Ba,
		2601.6	6.0	Bh,	2602.5	5.7	Ca,	2602.6	5.8	Bh,	2602.6	5.8	Pt,
		2602.6	5.1	Mu,	2603.6	5.7	Mo,	2603.6	5.9	Hu,	2603.6	5.8	Bh,
		2603.6	5.9	O,	2604.5	5.7	Ca,	2604.5	5.9	Ms,	2604.6	5.8	Bh,
		2605.5	5.8	O,	2605.5	5.4	K,	2605.5	5.8	Cl,	2605.5	5.9	Ms,

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
184205	R Scuti	2605.6	6.0	Bh,	2606.5	6.0	Hn,	2606.5	5.9	Ms,	2606.5	5.4	Cl,
		2606.5	5.7	Ca,	2606.6	6.0	Bh,	2607.5	5.7	Ms,	2607.5	5.7	Mo,
		2607.5	5.8	O,	2607.7	5.7	Mu,	2608.5	5.4	K,	2608.5	5.7	Ms,
		2608.5	5.3	Cl,	2608.5	5.7	Ca,	2608.5	5.7	Nc,	2608.8	4.8	Bs,
		2609.5	5.7	O,	2609.5	5.6	Cl,	2609.5	5.6	Ms,	2609.5	5.8	Wl,
		2609.5	5.9	Nc,	2609.6	5.4	Bh,	2610.5	5.7	Ca,	2610.5	5.4	Pt,
		2610.6	5.4	Mu,	2610.6	5.8	Bh,	2611.5	5.0	M,	2611.5	5.6	Ms,
		2611.5	5.6	Nc,	2612.6	5.4	Pi,	2612.6	5.0	Su,	2613.5	5.6	O,
		2613.5	5.4	Ms,	2613.5	5.6	Nc,	2615.5	5.6	O,	2615.5	5.4	Nc,
		2615.5	5.3	Ms,	2616.5	5.3	Ms.						
184243	RW Lyrae	2533.7	*13.0*	Ba,	2601.6	*13.5*	Ba,	2610.6	*14.0*	B.			
184300	Nova Aquil. 3	2533.6	8.9	Ba,	2544.1	8.5	Ch,	2563.6	9.1	Ba,	2571.3	8.4	L,
		2571.4	9.2	Gi,	2574.3	8.4	Pe,	2579.0	8.3	Pe_3,	2580.3	8.5	L,
		2580.3	9.2	Gi,	2587.5	9.0	Ro_5,	2588.6	8.8	Pt,	2596.3	8.6	L,
		2599.1	8.8	Bh_2,	2599.6	8.8	Pt_2,	2600.5	8.7	K,	2600.6	8.6	Ya,
		2601.1	9.0	Ro_5,	2601.5	9.2	Ba,	2603.6	8.9	V,	2605.5	8.5	Cl,
		2605.5	8.6	K,	2607.6	8.6	Bh_2,	2608.5	8.6	K,	2608.9	8.9	Ro_5,
		2609.1	8.9	B_2,	2611.5	8.8	Pt,	2611.5	8.7	M,	2612.5	8.4	Pi.
184929	Nova Lyrae 1	2569.4	12.6	Gi,	2579.4	12.6	Gi.						
185032	RX Lyrae	2601.6	13.5	Ba,	2607.6	*12.2*	Pi.						
185243	R Lyrae	2586.6	4.5	Bh,	2598.6	4.3	Bh,	2599.6	4.3	Bh,	2601.6	4.2	Bh,
		2602.6	4.2	Bh,	2603.6	4.2	Bh,	2604.6	4.3	Bh,	2605.6	4.3	Bh,
		2606.6	4.4	Bh.									
185512	ST Sagittarii	2612.6	*11.2*	Pi.									
185634	Z Lyrae	2610.6	14.0	B,	2611.6	*13.3*	Ba.						
190108	R Aquilae	2584.6	7.9	B,	2599.6	6.8	B,	2602.6	6.5	Pi,	2602.6	7.1	Pt,
		2611.6	6.0	M,	2611.6	6.4	Ba.						
190529a	V Lyrae	2601.6	*13.4*	Ba,	2605.5	*13.0*	Y.						
190818	RX Sagittarii	2600.6	*13.1*	B.									
190819a	RW Sagittarii	2600.6	10.1	B.									
190925	S Lyrae	2533.6	*13.0*	Ba,	2609.6	*13.8*	B.						
190926	X Lyrae	2533.7	8.3	Ba,	2611,6	8.9	Ba,	2614.6	9.1	M.			
190967	U Draconis	2533.7	12.3	Ba,	2605.6	11.6	Hu,	2612.6	14.0	Ba.			
191019	R Sagittarii	2574.4	*11.8*	Pe,	2601.5	10.8	Ba,	2602.6	11.2	Pi,	2603.6	10.5	Pt,
		2605.6	10.2	B.									
191033	RY Sagittarii	2531.6	6.3	Ba,	2563.6	6.0	Ba,	2570.6	6.0	Ba,	2575.3	6.2	L,
		2578.3	6.1	L,	2583.3	6.3	L,	2588.6	6.2	Pt,	2596.3	6.0	L,
		2596.5	6.3	Pt,	2600.5	6.3	Pt,	2601.5	6.7	Ba,	2602.6	6.3	Pt,
		2602.6	6.6	Pi,	2611.5	6.5	Pt.						
191319	S Sagittarii	2571.4	13.5	Gi.									
191321	Z Sagittarii	2571.4	9.2	Gi.									
191350	TZ Cygni	2533.6	10.5	Ba,	2605.5	10.6	Y,	2611.6	10.5	Ba.			
191637	U Lyrae	2586.7	10.7	Pt,	2601.6	10.0	Ba,	2612.5	11.0	Pi,	2615.5	10.9	M.
192928	TY Cygni	2601.6	12.8	Ba,	2603.6	12.1	Pt,	2607.6	*11.9*	Pi,	2612.6	12.3	M.
193311	RT Aquilae	2599.6	10.5	B,	2601.6	10.6	Ba.						
193449	R Cygni	2533.6	9.8	Ba,	2540.1	*12.0*	Ch,	2583.8	*10.9*	Ca,	2601.6	*13.1*	Ba,
		2610.6	13.9	B.									
193509	RV Aquilae	2586.7	12.3	Pt,	2612.6	*13.0*	Ba.						
193732	TT Cygni	2602.6	7.0	Hu,	2611.6	7.0	Ba.						
194048	RT Cygni	2533.6	7.3	Ba,	2540.1	7.3	Ch,	2541.6	7.1	My,	2576.5	9.1	Gi,
		2583.8	9.7	Ca,	2586.7	9.5	Pt,	2598.5	10.2	Gi,	2601.6	10.5	Ba,
		2602.6	10.1	Hu,	2603.6	*11.1*	V,	2605.5	11.3	Ya,	2608.7	11.7	Pi,
		2610.6	10.8	B,	2611.5	11.1	M.						

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
194348	TU Cygni	2533.6	11.8	Ba,	2586.7	9.6	Pt,	2601.6	9.4	Ba,	2602.6	9.5	Hu,
		2603.6	10.0	V,	2605.5	9.4	Ya,	2608.7	9.8	Pi,	2610.6	9.3	B,
		2611.5	10.0	M,	2611.7	10.5	Hl.						
194604	X Aquilae	2533.6	*12.0*	Ba,	2584.6	13.7	B,	2602.6	*12.3*	Pi,	2611.5	*10.2*	Jd.
194632	χ Cygni	2531.7	5.9	Ba,	2544.1	6.1	Ch,	2553.1	6.2	Ch,	2570.6	7.0	Ba,
		2573.4	7.4	Pe,	2574.3	7.4	Pe,	2577.4	7.4	Pe_4,	2588.8	8.0	Pt,
		2602.6	8.3	Hu,	2604.6	8.9	Ya,	2604.6	8.6	V,	2606.5	9.2	Cl,
		2606.7	8 9	Ca,	2607.0	9.2	K_o,	2607.6	9.0	Pi,	2609.1	8.6	B_o,
		2611.6	8.5	Ba,	2611.6	9.2	M,	2611.7	9.9	Hl.			
195116	S Sagittae	2583.7	6.3	Mu,	2585.7	5.8	Mu,	2588.7	5.3	Mu,	2599.7	5.8	Mu,
		2600.7	6.1	Mu,	2602.6	5.3	Mu,	2607.7	5.4	Mu,	2610.6	6.1	Mu.
195202	RR Aquilae	2584.6	12.6	B.									
195308	RS Aquilae	2588.6	12.2	B,	2610.6	13.8	B.						
195553	Nova Cygni 3	2560.6	2.3	My,	2561.4	1.8	Mt,	2561.6	2.0	My,	2562.4	2.3	Mt,
		2562.6	2.3	My,	2562.6	2.6	Wt,	2562.7	2.6	Ba,	2563.4	2.8	Mt,
		2563.5	2.8	Ba,	2563.6	3.0	Mt_3,	2563.6	2.8	Wt,	2563.6	3.2	My,
		2564.6	3.3	Wt,	2564.6	3.0	Ba,	2564.6	3.3	Hw,	2564.6	3.3	My,
		2565.4	3.2	Bp,	2565.4	3.6	Mt,	2565.6	3.9	My,	2565.6	3.4	Hw,
		2566.6	3.6	Ba,	2566.6	4.0	My,	2567.6	4.0	Ba,	2567.6	3.7	Wt,
		2568.5	4.0	Bp,	2568.6	4.2	Ba,	2568.6	4.2	My,	2569.3	4.2	Be,
		2569.4	4.2	Gi,	2569.4	3.9	Bp,	2569.5	4.3	L,	2569.6	4.2	My,
		2569.6	4.1	Wt,	2570.3	4.4	L,	2570.3	4.2	Pe,	2570.3	4.4	Be,
		2570.5	4.3	Ba,	2570.6	4.5	Wt,	2570.7	4.3	Ca,	2571.3	4.6	Be,
		2571.3	4.6	L,	2571.4	4.5	Bp,	2571.5	4.8	Gi,	2571.6	4.5	Wt,
		2571.6	4.3	My,	2571.6	4.8	Ms,	2571.6	4.5	Ca,	2571.6	4.6	L,
		2572.3	4.6	L,	2572.3	4.7	Be,	2572.3	4.6	Mt,	2572.5	4.9	Gi,
		2573.3	4.6	L,	2573.4	4.6	Be,	2573.4	5.0	Gi,	2573.4	4.4	Pe,
		2573.6	4.8	Wt,	2573.6	4.7	Ca,	2574.3	4.7	Pe,	2574.4	4.6	Bp,
		2574.5	4.9	Bp,	2574.6	4.5	My,	2574.6	4.9	L,	2575.3	4.8	Be,
		2575.3	4.7	L,	2575.4	4.6	Pe,	2575.4	4.8	Bp,	2575.4	5.2	Gi,
		2575.6	4.8	Wt,	2576.3	4.8	L,	2576.3	4.8	Pe,	2576.4	4.8	Be,
		2576.4	5.2	Gi_4,	2576.6	5.2	Wt,	2576.6	4.8	Hw,	2576.6	4.8	Ms,
		2576.6	5.3	Ca,	2577.3	4.9	Mt,	2577.4	5.1	Be,	2577.4	5.3	Bp,
		2577.5	5.4	Gi,	2578.3	5.1	L,	2578.3	5.2	Pe,	2578.4	5.1	Be,
		2578.4	5.5	Mt,	2578.5	5.5	Gi,	2578.6	5.3	L,	2579.3	5.4	Gi,
		2579.3	4.9	Pe,	2579.4	5.5	Mt,	2579.4	5.2	Bp,	2579.4	5.5	L,
		2579.6	5.6	L,	2579.6	4.8	Ms,	2579.6	5.0	Hw,	2580.3	5.1	Pe,
		2580.3	5.2	L,	2580.3	5.4	Be,	2580.4	5.5	Gi,	2580.6	4.9	Ms,
		2581.3	5.4	Be,	2581.3	5.4	Pe,	2581.3	5.4	L,	2581.6	5.6	Gi,
		2581.6	5.6	L,	2582.3	5.5	Pe,	2582.4	5.7	Be,	2582.4	5.6	L,
		2583.3	5.8	Be,	2583.3	5.7	L,	2583.3	5.8	Pe,	2583.5	5.9	Gi,
		2583.6	5.2	Ms,	2583.8	5.7	Ca,	2584.3	5.9	Mt,	2584.3	5.9	Gi,
		2584.4	6.0	Bp,	2584.4	5.7	L,	2585.4	6.0	Bp,	2585.5	6.0	Ro,
		2585.6	5.5	Hw,	2585.6	5.3	Ms,	2585.6	6.0	L,	2585.6	5.7	Wt.
		2586.4	6.1	L,	2586.4	6.3	Mt,	2586.5	6.3	Ro,	2586.7	6.4	Pt,
		2587.3	6.4	Mt,	2587.4	6.0	L,	2587.5	6.2	K,	2587.5	6.2	Gd.
		2587.5	6.3	Ro,	2587.6	5.7	Hw,	2587.6	6.2	O,	2587.6	5.8	V,
		2587.6	6.2	Pt,	2587.7	6.4	Ca,	2588.5	5.7	Ms,	2588.5	6.4	Ro,
		2588.8	6.5	Pt,	2589.3	6.1	Be,	2589.4	6.3	L,	2589.5	6.1	Cl,
		2589.5	6.6	Bp,	2589.5	6.0	O,	2589.5	6.5	Ro,	2589.6	6.1	Hw,
		2589.6	5.9	Ms,	2589.8	6.5	Pt,	2590.5	6.5	Ro,	2590.5	6.3	Ms,
		2590.5	6.3	O,	2591.3	6.3	L,	2591.3	6.3	Be,	2591.5	7.0	Wl,
		2592.4	7.2	Bp,	2593.4	6.9	Gi,	2593.7	7.4	L,	2594.3	7.2	Gi,
		2595.4	7.2	Gi,	2596.3	7.2	Gi,	2596.3	7.3	Bp,	2596.3	7.3	L,
		2596.4	6.6	Pe,	2596.5	7.0	Ro,	2597.2	6.9	Pe,	2597.3	7.3	Gi,
		2598.3	7.2	L,	2599 6	7.2	Mu,	2600.5	*7.2*	O,	2600.5	6.5	Ms,
		2600.5	7.5	Ro,	2600.7	7.3	Mu,	2601.5	7.8	Ro,	2601.5	6.7	Ms,
		2602.5	8.0	Ro,	2602.6.	7.4	Mu,	2602.6	6.9	Ms,	2604.5	8.1	Ro,
		2606.5	8.4	Ro,	2607.5	8.5	O,	2607.5	8.1	Pi,	2607.5	8.6	Ro,
		2607.6	8.4	Ya,	2607.6	8.4	Gd,	2608.5	8.4	Gd,	2608.5	8.8	Ro,
		2608.6	8.6	Ms,	2608.6	8.5	Jd,	2608.6	8.4	O,	2609.5	8.6	O,

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
195553	Nova Cygni 3	2609.5	8.6	Ms,	2609.5	8.9	Ro,	2609.5	8.4	Pi,	2609.6	8.2	Wl,
		2610.7	8.3	Ca,	2611.5	8.9	V,	2611.5	8.7	Ms,	2611.5	8.5	Gd,
		2611.6	8.2	Ba,	2611.6	8.4	B,	2612.5	9.0	Ro,	2612.5	8.5	Ya.
		2612.6	8.4	B,	2612.6	8.4	Wl,	2612.6	8.7	Su,	2612.6	8.5	M,
		2612.6	8.6	Y,	2612.6	8.6	O,	2613.5	8.6	O,	2613.6	8.7	Ms,
		2613.6	8.6	Jd,	2614.5	8.9	Gd,	2614.5	8.6	V,	2614.6	8.6	Pt,
		2615.5	8.7	O,	2615.5	8.6	Wl,	2615.5	8.6	Ms.			
195849	Z Cygni	2531.7	12.3	Ba,	2570.6	*12.7*	Gi,	2583.4	13.1	Gi,	2611.6	12.5	Pt,
		2611.6	*12.7*	Ba.									
200212	SY Aquilae	2533.6	*12.0*	Ba,	2575.4	*12.2*	L.						
200357	S Cygni	2608.7	*12.4*	Pi,	2612.7	*13.6*	B.						
200514	R Capricorni	2574.3	11.4	Gi.									
200647	SV Cygni	2602.6	8.3	Hu,	2605.6	9.0	Ya.						
200715a	S Aquilae	2573.4	9.4	Gi,	2586.6	9.4	B,	2595.4	9.1	Gi,	2599.6	9.4	Gd,
		2602.6	9.5	Pt,	2603.6	9.6	Ya,	2605.5	9.4	Cl,	2607.6	9.7	Pi,
		2609.6	10.0	M,	2611.6	9.5	Ba.						
200715b	RW Aquilae	2586.6	9.2	B,	2603.6	8.9	Ya,	2605.5	9.0	Cl,	2607.6	9.2	Pi,
		2611.6	9.3	Ba.									
200812	RU Aquilae	2605.6	11.7	B.									
200822	W Capricornii	2605.5	*12.6*	Y.									
200906	Z Aquilae	2569.4	*12.2*	Gi,	2583.4	*12.7*	Gi,	2584.6	*13.5*	B,	2599.6	*13.0*	B.
200916	R Sagittae	2603.6	9.1	Ya,	2605.5	9.1	Cl,	2611.6	8.9	Ba.			
200938	RS Cygni	2533.7	7.4	Ba,	2539.1	7.4	Ch_2,	2557.1	7.5	Ch,	2572.3	7.3	L,
		2583.6	7.2	L,	2588.8	7.5	Pt,	2600.6	7.2	Gd,	2605.6	7.5	Ya,
		2611.6	7.9	M.									
201008	R Delphini	2574.4	*12.8*	L,	2598.5	11.7	B,	2602.6	11.5	Pi.			
201121	RT Capricor.	2577.7	7.9	Pe_3,	2579.4	6.8	L_2,	2587.6	7.6	Wl,	2594.3	6.8	L,
		2600.7	8.0	Bs,	2603.5	8.1	Ya,	2605.5	7.8	Wl,	2607.5	7.9	Gd.
201130	SX Cygni	2533.7	*13.5*	Ba,	2605.6	*12.9*	Y,	2610.7	*13.5*	B.			
201139	RT Sagittarii	2600.5	10.6	Pt,	2602.6	10.6	Pi.						
201437a	P Cygni	2541.1	5.0	Ch,	2553.1	4.8	Ch.						
201647	U Cygni	2533.7	8.0	Ba,	2576.5	8.9	Gi,	2586.7	9.5	Pt,	2593.8	8.7	Ml,
		2599.5	9.5	Wl,	2600.5	9.8	Pi,	2600.6	9.0	Gd,	2603.6	8.2	Ya,
		2604.5	9.0	Ro,	2605.6	9.7	Wl,	2607.5	9.5	Pi,	2608.9	8.4	Ro_5,
		2611.6	9.6	M,	2614.5	9.5	Gd.						
202539	RW Cygni	2533.7	8.0	Ba,	2592.6	9.0	Wl,	2600.6	8.6	Gd.	2605.6	8.9	Wl.
202622	RU Capricor.	2574.4	10.4	Gi,	2599.6	11.7	B.						
202817	Z Delphini	2586.7	9.5	Pt,	2599.7	9.6	B,	2605.6	9.9	Hu,	2607.6	10.0	Pi.
202946	SZ Cygni	2533.7	8.9	Ba,	2563.6	8.9	Ba,	2570.6	9.3	Ba,	2601.6	9.2	Ba,
		2605.5	9.0	K,	2605.6	9.1	Ya,	2607.6	9.5	Hu,	2608.5	9.5	K.
202954	ST Cygni	2531.7	12.0	Ba,	2600.5	*12.1*	Pi.						
203226	V Vulpec.	2602.6	9.0	Pt.									
203611	Y Delphini	2599.7	9.4	B,	2601.5	10.5	O,	2603.6	10.2	Pt,	2605.5	10.6	O,
		2611.5	10.7	Gd.									
203816	S Delphini	2533.7	8.6	Ba,	2584.6	9.2	B,	2599.7	9.2	B,	2604.5	10.2	V,
		2605.5	10.0	Cl,	2607.6	10.0	Pi,	2614.6	9.7	M.			
203847	V Cygni	2541.1	9.8	Ch,	2570.6	9.2	Gi,	2595.4	9.7	Gi.	2612.7	11.1	B,
		2614.6	11.0	M.									
203905	Y Aquarii	2577.9	12.3	Pe_2.									
204104	W Aquarii	2577.4	13.3	Gi,	2578.3	*12.9*	L.						
204215	U Capricor.	2575.3	*13.9*	Gi.									
204318	V Delphini	2533.7	*12.5*	Ba,	2569.4	*12.5*	Gi,	2583.5	*12.5*	Gi,	2611.6	*13.0*	B.

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
204405	T Aquarii	2533.7	8.8	Ba,	2540.2	8.0	Ch,	2546.2	7.8	Ch,	2557.1	7.6	Ch,
		2578.0	7.5	Pe_2,	2586.7	7.7	Pt,	2587.5	8.0	Wl,	2601.6	8.4	Ba,
		2602.5	8.8	Hn,	2602.5	8.9	Pi,	2603.6	8.6	Ya,	2605.6	8.8	B,
		2607.0	8.9	Wl_2,	2607.6	8.9	Hu,	2609.0	8.9	Ro_2.			
204846	RZ Cygni	2570.7	11.5	Gi,	2583.5	11.5	Gi,	2598.5	11.5	Gi.			
205923	R Vulpec.	2577.4	11.4	Gi,	2596.4	9.7	Gi,	2602.6	9.4	Pt,	2605.6	9.2	B,
		2606.7	7.8	Hl,	2607.6	8.5	Hu,	2607.7	9.1	Pi,	2615.6	8.0	M.
210116	RS Capricor.	2580.4	8.4	Pe_2,	2587.5	8.7	Wl,	2602.5	7.9	Hn,	2602.6	8.1	Mu,
		2602.6	8.0	Pi,	2603.5	8.2	Ya,	2605.5	8.5	Wl.			
210124	V Capricor.	2576.4	*12.7*	Gi.									
210129	TW Cygni	2611.5	*13.0*	Y.									
210221	X Capricor.	2576.4	13.0	Gi.									
210504	RS Aquarii	2570.3	11.5	L,	2583.3	10.1	L.						
210812	R Equulei	2595.6	9.2	Ml,	2601.6	9.0	Ba.						
210868	T Cephei	2531.7	9.2	Ba,	2541.1	9.5	Ch,	2570.7	9.8	Ml,	2574.6	9.9	L,
		2583.6	10.4	L,	2588.8	10.4	Pt,	2592.9	10.1	Ml,	2605.6	9.5	Hu,
		2608.1	9.8	Hw_2,	2608.7	10.1	Pi,	2609.8	9.8	Ms_4,	2615.5	9.2	Ms,
		2615.6	9.8	M,	2615.6	10.0	Ya.						
210903	RR Aquarii	2571.8	10.3	Ml.									
211614	X Pegasi	2533.7	9.7	Ba,	2579.4	10.0	Gi,	2605.6	10.9	Y,	2607.5	10.9	O,
		2607.7	10.5	Pi.									
211615	T Capricor.	2571.8	9.5	Ml,	2600.5	11.8	Gd,	2601.6	11.7	Ba,	2602.6	*11.8*	Pi,
		2603.5	11.8	Ya.									
213244	W Cygni	2570.3	5.8	L,	2577.3	5.8	L,	2583.3	5.7	L,	2591.3	5.9	L,
213678	S Cephei	2531.7	8.8	Ba,	2569.5	9.5	Gi,	2581.6	10.0	Gi,	2593.8	9.5	Ml,
		2596.5	10.2	Gi,	2599.7	11.8	Hl,	2605.6	10.0	Hu,	2605.7	10.5	B,
		2608.6	*10.2*	Hw,	2608.7	11.4	Pi,	2613.6	*10.2*	Ms,	2615.8	*10.2*	Hw
213753	RU Cygni	2612.5	9.9	Ya,	2615.6	10.0	M.						
213843	SS Cygni	2531.7	11.5	Ba,	2533.6	11.5	Ba,	2545.1	12.0	Ch,	2553.1	11.9	Ch,
		2563.5	12.1	Ba,	2569.3	8.6	Gi,	2569.6	8.4	L,	2570.3	8.2	L,
		2570.5	8.7	Ba,	2570.6	8.3	L,	2571.3	8.3	L,	2571.5	8.6	Gi,
		2572.3	8.3	L,	2574.3	8.7	Gi,	2574.3	8.4	Pe,	2574.6	8.5	L,
		2575.3	8.4	L,	2575.6	8.5	L,	2576.3	8.5	L,	2576.5	8.8	Gi,
		2576.6	8.7	L,	2577.5	8.9	Gi,	2578.3	8.6	L,	2579.5	9.7	Gi,
		2579.6	9.7	L,	2580.3	9.8	L,	2580.4	10.0	Gi,	2581.3	10.2	L,
		2581.6	10.7	Gi,	2582.5	11.1	B,	2583.3	10.9	L,	2583.5	11.3	Gi,
		2584.5	11.7	B,	2584.6	11.7	L,	2585.5	12.0	Ro,	2585.6	11.7	L,
		2585.6	11.9	B,	2586.3	11.9	Gi,	2586.5	12.0	Ro,	2586.5	12.0	B,
		2586.7	11.9	Pt,	2587.5	12.0	Ro,	2587.5	12.1	Gd,	2588.6	12.0	Pt,
		2589.5	12.0	B,	2589.8	12.0	Pt,	2591.3	11.8	L,	2592.5	11.8	Ba,
		2593.6	11.9	L,	2595.4	12.1	Gi,	2596.5	11.9	Pt,	2598.3	11.7	L,
		2598.4	12.0	Gi,	2598.5	11.9	B,	2598.5	12.2	Gd,	2599.5	12.0	B,
		2599.5	*12.0*	Wl,	2600.5	12.0	Ro,	2600.5	11.9	Pt,	2600.5	11.5	K,
		2600.6	12.0	B,	2601.5	11.9	Ba,	2601.6	11.9	Pt,	2602.5	12.0	Ro,
		2602.5	12.0	Pi,	2602.6	11.9	Hu,	2602.6	12.0	Pt,	2603.5	12.0	Pi,
		2603.6	11.8	Ya,	2604.5	*11.3*	V,	2604.5	11.9	Pt,	2604.5	12.1	Gd,
		2604.5	12.0	B,	2605.5	11.9	Pi,	2605.5	11.9	K,	2605.5	12.0	B,
		2605.5	11.7	Cl,	2605.7	11.9	Pt,	2606.5	12.0	B,	2606.5	12.0	Cl,
		2606.7	11.9	Ca,	2606.8	12.0	Pt,	2607.5	11.9	B,	2607.6	12.0	Pi,
		2608.5	12.0	B,	2608.5	12.0	K,	2608.5	12.0	Cl,	2608.7	12.0	Pi,
		2608.7	12.3	Jd,	2609.5	12.0	B,	2609.5	11.8	Ro,	2610.6	12.0	B,
		2610.7	11.9	Ca,	2611.5	12.1	Y,	2611.5	12.1	Gd,	2611.6	*12.1*	Jd,
		2611.6	11.9	Ba,	2611.6	12.1	M,	2611.6	12.0	Pt,	2611.6	12.0	B,
		2612.5	11.8	Ba,	2612.5	11.5	Ro,	2612.6	12.2	Wl,	2612.7	12.0	B,
		2614.6	12.1	Gd,	2615.5	12.1	O,	2615.5	12.2	Wl.			
213937	RV Cygni	2607.6	7.3	Hu,	2611.6	7.8	M,	2612.5	8.3	Ya.			
214024	RR Pegasi	2533.7	12.0	Ba,	2600.6	9.6	B,	2603.6	9.6	Pt,	2607.7	9.9	Pi,
		2608.6	10.3	Gd,	2615.6	10.4	M.						

VARIABLE STAR OBSERVATIONS, September 20 to October 20, 1920—Continued.

Number	Name	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
215605	Y Pegasi	2531.7	13.7	Ba.									
215934	RT Pegasi	2611.5	11.2	Y.									
220412	T Pegasi	2531.7	11.5	Ba,	2571.5	12.7	Gi,	2572.3	*12.0*	L,	2584.4	13.3	Gi.
220613	Y Pegasi	2531.7	12.8	Ba,	2571.5	10.4	Gi,	2595.4	11.6	Gi,	2607.7	*12.5*	Pi.
220714	RS Pegasi	2531.7	10.9	Ba,	2571.5	11.6	Gi,	2581.6	12.0	B,	2584.4	12.2	Gi,
		2607.7	*12.5*	Pi.									
222129	RV Pegasi	2586.6	10.2	B.									
222439	S Lacertae	2531.7	11.7	Ba,	2577.4	12.8	Gi,	2578.3	*12.4*	L,	2593.9	12.4	Ml,
		2601.6	12.4	Ba,	2603.5	11.4	Pi.						
223841	R Lacertae	2572.3	*12.3*	L,	2577.4	13.7	Gi,	2583.6	*12.3*	L,	2596.4	11.3	Gi,
		2598.3	11.7	L.									
225120	S Aquarii	2586.6	12.1	B,	2601.6	12.7	Ba,	2602.6	*11.3*	Pi,	2605.6	13.2	Y,
		2611.6	13.3	B.									
225914	RW Pegasi	2533.7	9.8	Ba,	2598.6	11.5	B,	2599.5	11.3	Gd,	2601.5	10.8	O,
		2602.6	11.1	Mu,	2603.5	11.7	Pi,	2604.6	*11.0*	V,	2605.6	11.5	Y,
		2615.6	11.8	M.									
230110	R Pegasi	2599.6	*11.0*	Wl,	2602.5	*10.9*	Hn,	2606.5	*12.0*	Ro,			
		2607.6	*10.1*	Jd,	2609.5	*12.0*	Ro,	2612.6	12.2	Wl.			
230759	V Cassiop	2531.7	11.9	Ba,	2569.5	9.8	Gi,	2574.4	10.2	Pe,	2581.6	9.5	Gi
		2587.6	9.5	Gd,	2589.5	9.8	O,	2591.6	9.8	Wl,	2596.5	9.4	Gi
		2598.6	9.2	B,	2600.6	9.5	O,	2602.2	9.7	Ro_4,	2603.5	9.5	Pi
		2603.6	9.4	Pt,	2604.6	9.1	V,	2605.5	9.2	O,	2608.5	8.8	Wl,
		2609.5	9.4	Ro_5,	2612.6	9.0	M,	613.5	8.6	O,	2615.6	8.7	Ya
231425	W Pegasi	2531.7	11.9	Ba,	2572.3	*12.4*	L,	2580.3	12.3	L,	2603.6	11.8	Pi
		2607.6	11.6	Hu.									
231508	S Pegasi	2531.7	10.1	Ba,	2574.4	9.0	Pe,	2580.0	8.4	Pe_4,	2599.5	8.0	B
		2600.6	7.4	Pt,	2601.0	8.0	O_5,	2605.5	8.0	O,	2607.5	9.2	Jd
		2613.5	8.4	O.									
232848	Z Androm.	2610.2	10.0	O_4.									
2333335	ST Androm.	2544.2	*10.9*	Ch,	2602.6	11.4	Pt,	2603.5	11.5	Pi,	2603.5	11.0	O
		2605.5	10.4	Cl,	2607.6	11.5	Hu,	2608.5	11.4	K,	2609.6	11.2	B
		2614.7	11.1	M.									
233815	R Aquarii	2544.4	10.3	Ch,	2575.4	10.2	Pe,	2587.6	10.0	Ca,	2593.8	9.8	Ml
		2601.6	9.7	Ba,	2601.7	10.0	Ca,	2602.6	10.3	Pi,	2605.6	9.8	Ya
		2610.6	9.9	Ca,	2611.6	9.9	Pt,	2612.6	9.6	B.			
233956	Z Cassiop	2531.7	9.5	Ba,	2586.6	11.2	B,	2603.5	11.6	Pi,	2615.5	12.5	M
235053	RR Cassiop	2586.6	12.5	B,	2611.6	13.4	B.						
235209	V Ceti	2574.6	*11.7*	L,	2585.6	*12.4*	L.						
235350	R Cassiop	2531.7	6.6	Ba,	2570.9	7.7	Ml,	2573.4	8.0	Gi,	2598.5	8.4	Gi
		2603.5	9.0	Pi,	2606.6	8.7	B,	2612.6	9.4	M,	2612.6	8.8	B
235525	Z Pegasi	2587.6	10.4	O,	2602.6	11.3	Pt,	2603.6	10.6	O.			
235855	Y Cassiop	2531.7	*13.0*	Ba,	2569.5	*13.0*	Gi,	2581.6	13.3	Gi,	2598.6	12.5	B
		2614.6	10.2	M.									
235939	SV Androm.	2601.5	10.6	O,	2602.6	10.7	Pt,	2603.5	10.8	Pi,	2605.6	11.0	Y
		2607.6	10.8	Hu,	2609.6	10.2	B,	2614.6	10.0	M.			

Total observations: 2011. Stars Observed: 260. Observers: 37.

Clement "Cl," Ginori "Gi," Godfrey "Gd," Hall "Hl," Miss Harwood "Hw," Henckel "Hn," Hunter "Hu," Jordan "Jd," Kimball "K," Lacchini "L," McAteer "M," Merrill "Ml," Merton "Mt," Mrs. Morris "Ms," Mundt "Mu," Murray "My," Mrs. Norcross "Nc," Olcott "O," Mrs. Olcott "Mo," Peltier "Pt," de Perrot "Pe," Pickering "Pi," Rhorer "Ro," Suter "Su," Vrooman "V," Waldo "Wl," White "Wt," Yalden "Ya," and Miss Young "Y."

HOWARD O. EATON, Recording Secretary.

THE NINTH ANNUAL MEETING OF THE A. A. V. S. O.

By Geo. Waldo, Jr.

Members of the American Association of Variable Star Observers gathered at Cambridge, Mass., on November 6 for their ninth annual meeting, beginning with an informal get-together at the Harvard College Observatory in the morning, and concluding with a banquet at the Parker House, Boston, in the evening, at which Donald B. MacMillan, polar explorer, was the guest of honor. The success of the meeting, the large attendance, the many interested guests present, the enthusiastic reports from the officers and sub-committees,—all attested, not only to the growth and prosperity of the Association, but to an ever increasing spread of popular interest in the king of all sciences—Astronomy.

As the reports of the various officers and committees disclosed a membership now exceeding 200, with a total of over 110,000 observations to the credit of the Association, and a rapidly widening circle of members and active observers, it is evident that the watch on the important variables will be kept with ever increasing vigilance and accuracy.

The advance guard of the Association arrived in Boston on Friday and by nightfall a large number had come. No time was lost in getting together in one of those informal conversaziones which are an enjoyable feature of all such events.

Saturday's busy program, culminating with a banquet at the Parker House, was followed to the dot as laid out by the Committee on arrangements. In order to get in all the good things as planned, it was necessary to adhere to railroad schedule.

First on the program was the council meeting in the morning, which was held at the Observatory. While the council was in session, other members of the Association roamed about the Observatory buildings, examined the apparatus and made the most of the opportunity for talking with various members of the Observatory staff, who combined, under the leadership of the Acting Director, to make the visitors feel very much at home.

At noon a dozen members lunched together at one of the Cambridge inns, returning immediately to the Observatory grounds for the regular business meeting, which was held at the residence, so long the home of the Association's counsellor, friend and tireless partisan, the late Professor Edward C. Pickering.

Acting Director S. I. Bailey welcomed the Association with a gracious invitation to all to observe the occasion in the spirit of the Spanish saying which makes the guest a partner in the ownership of the house. The business meeting was formally called to order by President Campbell, and opened with the reading of the records of the previous meeting by the Secretary, W. T. Olcott, and the report of the Treasurer, Mr. A. B. Burbeck.

For the telescope committee the chairman, Miss Annie J. Cannon, reported 14 instruments now under the control of the Association, of which number six are owned outright and eight loaned—all doing excellent service in the variable star cause. One of the telescopes is in far away Japan and the others are scat-

tered about where they will do the most good. Miss Cannon closed her report by reading an interesting plea published by the late Professor Pickering in 1883, in which he expressed his surprise at the small number of women then engaged in observational astronomy and suggesting the possibilities of arousing greater interest.

Professor Bailey, for the slide committee, reported that the Association now has 462 slides, including selections from the cameras of the largest observatories, and covering the most interesting features of the heavens. An increasing demand for the loan of collections for exhibition purposes was reported with gratification by the committee. Professor Bailey urged all members to make good use of the loan collection, and thus to spread interest in astronomy. Later, as a part of the entertainment of the afternoon, a number of the slides were put on the screen and explained briefly by Mr. M. J. Jordan, thus fully justifying all that had been said about them. A printed catalogue—2nd edition—is being prepared, and it is anticipated that the slides will be kept busy in the coming year.

David B. Pickering, chairman of the chart committee, reported in behalf of that hard-working organization that the work of recharting the variables, so that all active members may be supplied with uniform blue-prints covering equal areas of sky and with the latest approved Harvard magnitudes, has now been completed for half of the sky. The committee has 175 charts available covering 125 regions. The work of preparing and distributing thousands of prints from the tracings that have been prepared entails considerable expense, and this is being met from a voluntary chart fund, to which a number of the members are contributing, in order that all active members may be supplied with charts without cost. The work of charting all the variables, Chairman Pickering reported, is progressing steadily, but it will necessarily be another year or two before it can be completed. Many practical difficulties are encountered, to the solution of which Harvard always lends a willing hand.

Calling the vice-president, Miss Anne S. Young, to the chair, President Campbell then read his presidential address for the year, detailing the growth of the Association in that period, its accession of new members and the great interest exhibited in the work. He congratulated the members on the number and quality of the observations turned in, and reiterated the real scientific value of the accumulated data. Incidently the President outlined to the members a program for additional service to the cause of astronomy, by each member's undertaking to keep regular watch on a certain portion of the sky for the appearance of novae, comets or other interesting features. By thus dividing the sky into regular "beats" and assigning one or more members to patrol each beat, the president hoped that to a member of the A.A.V.S.O. might fall the honor and credit of discovering the next visual nova. Charts indicating the divisions of the sky-areas —equivalent to about two hours in right ascension and 20 degrees in declination— were exhibited and many of the members undertook their assignments before the meeting was over.

The secretary read a communication from Professor C. P. Olivier of the University of Virginia, Charlottesville, Va., asking for the co-operation of the A. A. V. S. O. in observing telescopic meteors. The communication pointed out that the very nature of the work of observing variables made it possible to render real service with no additional effort in this respect, the members being able to locate with great precision the position of any meteor that swept across the field of their instrument, and also to estimate its magnitude with a fair degree of exact-

ness. It was recommended by the council that the members undertake to report any observations thus made, and a vote to that effect was passed unanimously.

While the ballots for the annual election were being counted, the members posed for a group photograph and then returned to hear the results of the election as follows:

President, Leon Campbell, Cambridge, Mass.
Vice-President, Anne S. Young, South Hadley, Mass.
Secretary, Wm. Tyler Olcott, Norwich, Conn.
Treasurer, Allan B. Burbeck, North Abington, Mass.
Elected to the council for two years, Annie J. Cannon, Cambridge, Mass., and J. Ernest G. Yalden, Leonia, N. J.

Mr. Yalden read an interesting and timely paper presented by Professor W. P. Gerrish on a simple method to be used in setting the polar axis of an equatorial telescope.

After the business meeting the members split into two groups, one repairing immediately to enjoy tea as the guests of Miss Cannon, aided by her staff of assistants, and the other group repairing to the laboratory to witness a demonstration of the silvering of a telescopic mirror.

The demonstration, which was made on one of the "flats," was skillfully carried to a successful conclusion by Mr. F. L. Bowie, of the Observatory staff, and was convincing proof of the simplicity of what (to most amateurs) is something of a bugaboo. It was shown that the length of time required and the manipulation of chemicals, etc., is certainly not greater than in the development and printing of an ordinary photographic plate.

Following the demonstration, Miss Cannon's tea, and the lantern slide exhibition, some of the members were given a chance to look at objects through the 12-inch reflector-refractor, which has its eye-end inside the room devoted to the interests of the A. A. V. S. O. To the inquiring eyes placed at this instrument, SS Cygni demonstrated its sulky refusal to come up to maximum on the plotted schedule.

The program now required a hasty return to Boston in order that the members might assemble at the Parker House for the annual banquet. About seventy sat down to the excellent meal which had been prepared—a record gathering in the history of the Association. Mr. S. C. Hunter of New Rochelle presided as toastmaster and discharged his duties very ably. He first called on Edwin F. Sawyer of Boston, one of the pioneer amateur observers of variable stars in America, and Mr. Sawyer responded by recounting some of the difficulties of observing in the old days, when each observer had to plot his own charts and work up his own magnitudes.

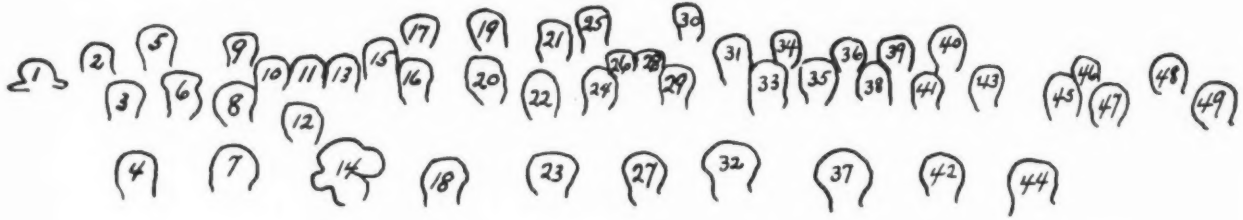
Professor J. R. Jewett, of the Harvard University faculty, spoke interestingly of Arabic star names; Miss Cannon made a brief but interesting and witty address; Professor A. P. Saunders of Hamilton College told of the revival of interest in astronomy there and in smaller colleges generally, and finally the Association's secretary, W. Tyler Olcott of Norwich, Conn., told of those early days and how little the first tiny group of enthusiasts expected ever to see the Association grow into an organization with over 200 members and such a fine record of achievement.

The guest of honor, Donald B. MacMillan, F. R. G. S., companion of Peary on his epochal trip to the North Pole and subsequently the leader of his own

PLATE XXV

THE NINTH ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS, AT HARVARD COLLEGE OBSERVATORY, NOVEMBER 6, 1920.

Key to Plate



1. Mrs. M. L. Spinney
2. F. H. Spinney
3. Miss E. F. Leland
4. Miss A. D. Walker
5. C. T. Whitehorn
6. H. R. Schulmaier
7. Miss A. M. Hawes
8. Miss F. Cushman
9. J. J. Crane
10. Miss C. Schulmaier
11. Miss M. Harwood
12. Miss M. A. Gill
13. E. W. Clement
14. Mrs. R. H. Brown
15. S. C. Hunter
16. W. T. Olcott
17. W. Henry
18. Mrs. W. H. Beach
19. A. P. Saunders
20. A. C. Perry
21. J. E. G. Yalden
22. L. Campbell
23. Miss D W. Reed
24. D. B. Pickering
25. P. H. Emerson
26. H. E. Melzar
27. Miss H. S. Leavitt
28. C. W. Elmer
29. F. C. Thompson
30. E. H. Bryan, Jr.
31. W. J. Delmhorst
32. Mrs. W. T. Olcott
33. C. C. Godfrey
34. C. A. Mowry
35. G. C. Waldo, Jr
36. G. C. Waldo, Jr.
37. Miss A. J. Cannon
38. M. J. Jordan
39. Mr. Boss
40. R. H. Brown
41. R. B. Macdonald
42. Miss A. S. Young
43. J. L. Peters
44. Miss I. E. Woods
45. M. E. Nielsen
46. D. Potter
47. A. Tarwater
48. S. I. Bailey
49. A. B. Burbeck

polar expedition which spent four years in the Far North, held the gathering spellbound as he described the long days and long nights of the Arctic, where Polaris gleams down from overhead. In addition to drawing most interestingly here and there from his store of Polar knowledge and folk-lore and other thrilling experiences, the speaker dwelt particularly upon the value and necessity of astronomy in the Far North, where the unpolluted air is at times so clear, "that you can reach out and touch the stars" and where the compass, no longer a reliable guide, must be checked by daily observations and constantly corrected for variations.

Though Saturday night's highly successful dinner concluded the main portion of the program, a dozen or more of the enthusiasts met again on Sunday morning to go with President Campbell to the observatory at Wellesley College, where under the able guidance of Miss Leah B. Allen, the Acting Director, they inspected the very complete and model equipment of the beautiful Whitin Observatory. All who went felt amply repaid for their visit and were able to appreciate the ideal conditions under which astronomy is taught at Wellesley.

Thus concluded the program attendant upon the ninth annual meeting of the Association, a meeting marked by enthusiasm and interest and one to be remembered with most pleasant associations.

VARIABLE STARS.

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1921 January					
	h m	° ′		d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7		12 14				
SY Cassiop	0 09.8	+57 52	9.3— 9.9	4 1.7		7 19	15 22		24 1	
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	5 10	13 11	20 4		28 22	
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2		11 7	26 3			
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 14	13 12	21 11		29 9	
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	3 20	11 15	19 11		27 5	
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	4 10	11 17	18 23		26 6	
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0		15			31	
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	11 20	20 11	29 8			
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	4 5	15 8	26 11			
RX Aurigæ	4 54.5	+39 49	7.2— 8.1	11 15.0		8 16	20 7		31 22	
SX Aurigæ	5 04.6	+42 02	8.0— 8.7	1 12.8	3 8	11 2	18 16		26 8	
SY Aurigæ	05.5	+42 41	8.4— 9.5	10 03.3		9 4	19 7		29 10	
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	1 19	9 13	17 6		25 0	
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	2 15	8 4	19 5		24 18	
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	3 12	11 1	18 15		26 5	
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3		17 13				
RT Aurigæ	23.0	+30 33	5.1— 6.0	3 17.5	8 11	15 22	23 9		30 20	
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	5 21	13 2	20 7		27 12	
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	4 8	12 6	20 4		28 1	
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	3 5	13 8	23 12			
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5	7 14		29 20			
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	5 5	13 3	21 2		29 1	
V Carinæ	8 26.7	—59 47	7.4— 8.1	6 16.7	2 16	9 9	22 18		29 11	

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1921 January							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
T Velorum	8 34.4	—47 01	7.6— 8.5	4 15.3			6 1	15 7	24 14			
V Velorum	9 19.2	—55 32	7.5— 8.2	4 08.9			6 23	15 17	24 10			
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 00.0								
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	6 1	12 20	19 15	26 10				
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	5 10	12 1	18 15	25 6				
S Muscæ	12 07.4	—69 36	6.4— 7.3	9 15.8	6 20	16 12	26 4					
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	6 7	14 6	22 6	30 5				
T Crucis	15.9	—61 44	6.8— 7.6	6 17.6	6 7	13 1	19 18	26 12				
R Crucis	18.1	—61 04	6.8— 7.9	5 19.8	8 17	14 13	20 9	26 5				
S Crucis	12 48.4	—57 53	6.5— 7.6	4 16.6	4 21	9 14	18 23	23 16				
W Virginis	13 20.9	— 2 52	8.7—10.4	17 06.5		18 5						
SS Hydræ	25.0	—23 08	7.4— 8.1	8 04.8	2 10	10 14	18 19	27 0				
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	8 20	15 20	22 21	29 21				
ST Virginis	14 22.5	— 0 27	10.3—11.4	0 09.9	2 7	10 12	18 17	26 22				
V Centauri	25.4	—56 27	6.4— 7.8	5 11.9	5 1	10 13	21 13	27 1				
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	5 2	12 15	20 4	27 17				
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	1 19	9 5	24 1	31 11				
R Triang. Austr.	15 10.8	—66 08	6.7— 7.4	3 09.3	5 1	11 19	18 14	25 9				
S Triang. Austr.	15 52.2	—63 29	6.4— 7.4	6 07.8	3 18	9 16	22 7	28 15				
S Normæ	16 10.6	—57 39	6.6— 7.6	9 18.1	4 22	14 16	24 10					
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	5 23	14 20	23 16					
RV Scorpii	16 51.8	—33 27	6.7— 7.4	6 01.5	4 17	10 19	22 22	28 23				
X Sagittarii	17 41.3	—27 48	4.4— 5.0	7 00.3	7 21	14 22	21 22	28 22				
Y Ophiuchi	47.3	— 6 07	6.1— 6.5	17 02.9	8 23		26 2					
W Sagittarii	17 58.6	—29 35	4.3— 5.1	7 14.3	4 3	11 17	19 8	26 22				
Y Sagittarii	18 15.5	—18 54	5.4— 6.2	5 18.6	1 20	7 15	19 4	30 17				
U Sagittarii	26.0	—19 12	6.5— 7.3	6 17.9	1 12	8 5	21 17	28 11				
Y Scuti	32.6	— 8 27	8.7— 9.2	10 08.3	1 0	11 9	27 17					
Y Lyræ	34.2	+43 52	11.3—12.3	0 12.1	1 9	7 10	19 11	25 12				
RZ Lyræ	18 39.9	+32 42	9.9—11.2	0 12.3	5 21	12 0	24 6	30 10				
RT Scuti	18 44.1	—10 30	9.1— 9.7	0 11.9	5 9	11 8	23 6	29 4				
κ Pavonis	18 46.6	—67 22	3.8— 5.2	9 02.2	3 13	12 15	21 17	30 20				
U Aquilæ	19 24.0	— 7 15	6.2— 6.9	7 00.6	3 23	10 23	18 0	25 0				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	4 18	11 18	18 18	25 18				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	1 0	9 0	16 23	24 23				
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	3 22	11 15	19 8	27 0				
η Aquilæ	47.4	+ 0 45	3.7— 4.5	7 04.2	2 13	9 17	16 21	24 1				
S Sagittæ	51.5	+16 22	5.6— 6.4	8 09.2	5 14	13 9	22 8	31 17				
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	6 5	12 12	18 20	25 14				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	2 18		19 3					
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	4 8	8 17	17 14	26 11				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	6 4	12 21	19 15	26 8				
RV Capric.	55.9	—15 37	9.2—10.1	0 10.7	1 17	8 10	21 20	28 13				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4		7 17	22 10					
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	7 15	15 11	23 7	31 4				
SW Aquarii	10.2	— 0 20	9.9—10.8	0 11.0	7 4	14 1	20 23	27 20				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	8 16	13 12	23 6	28 2				
Y Lacertæ	22 05.2	+50 33	9.1— 9.6	4 07.8	3 19	12 11	21 2	29 18				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	2 6	7 15	18 8	23 16				
Z Lacertæ	36.9	+56 18	8.2— 9.0	10 21.1	6 22	17 19	28 16					
RR Lacertæ	37.5	+55 55	8.5— 9.2	6 10.1	6 8	12 18	19 4	25 14				
V Lacertae	44.5	+55 48	8.5— 9.5	4 23.6	1 15	11 15	21 14	26 14				
X Lacertæ	22 45.0	+55 54	8.2— 8.6	5 10.7	6 0	11 10	16 21	22 8				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	4 8	9 18	20 15	26 2				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	1 5	7 12	20 2	26 9				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	7 13	19 16	31 19					
V Cephei	23 51.7	+82 38	6.0— 7.0	0 23.9	7 4	14 4	21 3	28 3				

Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900		Decl. 1900		Magnitude	Approx. Period		Greenwich mean times of minima in 1921 January							
	h	m	°	′		d	h	d	h	d	h	d	h	d	h
SY Androm.	0	08.0	+43	09	9.5—13.0	34	21.8							28	13
RT Sculptor.		31.5	—26	13	9.6—10.5	0	12.3	1	12	9	4	16	20	24	12
UU Androm		38.5	+30	24	10.7—11.9	1	11.7	6	3	13	14	21	0	28	11
U Cephei	0	53.4	+81	20	7.0— 9.0	2	11.8	5	13	13	0	20	12	27	23
Z Persei	2	33.7	+41	46	9.4—12	3	01.4	1	3	13	8	25	14	31	16
TW Cassiop.		37.6	+65	19	8.2— 9.0	1	10.3	7	8	14	12	21	15	28	18
RY Persei		39.0	+47	43	8.0—10.3	6	20.7	1	19	8	15	22	9	29	6
RZ Cassiop.		39.9	+69	13	6.9— 8.1	1	04.7	3	10	10	14	17	18	24	22
TX Cassiop.		44.4	+62	22	9.4—10.1	2	22.2	6	3	14	22	23	16		
ST Persei		53.7	+38	47	8.5—10.5	2	15.6	8	12	16	11	24	10		
RX Cassiop.	2	58.8	+67	11	8.6— 9.1	32	07.6					23	22		
Algol	3	01.7	+40	34	2.3— 3.5	2	20.8	4	10	10	4	21	15	27	9
RT Persei		16.7	+46	12	9.5—11.5	0	20.4	4	1	10	20	24	10	31	6
λ Tauri		55.1	+12	12	3.3— 4.2	3	22.9	2	17	10	15	18	12	26	10
RW Tauri	3	57.8	+27	51	7.1—<11	2	18.5	1	22	10	5	18	13	26	20
RV Persei	4	04.2	+33	59	9.5—11.0	1	23.4	4	23	12	21	20	18	28	16
RW Persei		13.3	+42	04	8.8—11.0	13	04.8	7	11			20	16		
SZ Tauri		31.4	+18	20	7.2— 7.7	3	03.6	4	6	13	17	23	4		
RS Cephei	4	48.6	+80	06	9.5—12.0	12	10.1	2	5	14	15	27	1		
TT Aurigæ	5	02.8	+39	27	7.8— 8.7	0	16.0	7	14	14	6	20	22	27	14
RY Aurigæ		11.5	+38	13	10.7—11.7	2	17.5	6	17	14	21	23	2	31	6
RZ Aurigæ		42.9	+31	40	10.6—13.3	3	00.3	4	19	10	20	22	21	28	21
SV Tauri		45.8	+28	05	9.4—11.0	2	04.0	6	10	15	2	23	18		
Z Orionis		50.2	+13	40	9.7—10.7	5	04.9	8	11	18	20	29	6		
SV Gemin.		54.6	+24	28	9.8—<11	4	00.2	3	12	11	12	19	13	27	13
RW Gemin.	5	55.4	+23	08	9.5—11.0	2	20.8	5	12	11	5	22	16	28	10
U Columbæ	6	11.2	—33	03	9.2—10.0	2	19.2	5	20	11	10	22	15	28	5
SX Gemin.		22.0	+20	37	10.8—11.5	1	08.8	4	15	12	20	21	1	29	5
RW Monoc		29.3	+ 8	54	9.0—10.8	1	21.7	7	10	15	1	22	16	30	7
RX Gemin.		43.6	+33	21	8.8— 9.6	12	05.0	4	15	16	20	29	0		
RU Monoc.	6	49.4	— 7	28	9.8—10.5	0	21.5	1	6	8	10	22	18	29	22
R Can. Maj.	7	14.9	—16	12	5.8— 6.4	1	03.3	2	13	9	9	16	5	23	0
RY Gemin.		21.7	+15	52	8.9—<10	9	07.2	3	11	12	19	22	2	31	9
Y Camelop.		27.6	+76	17	9.5—12	3	07.3	2	16	9	7	22	12	29	3
TX Gemin.		30.3	+17	08	10.0—11.9	2	19.2	6	0	14	10	22	20	31	5
RR Puppis		43.5	—41	08	9.4—10.7	6	10.3	3	2	9	0	22	21	29	7
V Puppis	7	55.4	—48	58	4.1— 4.8	1	10.9	3	14	10	20	18	3	25	9
X Carinae	8	29.1	—58	53	7.9— 8.7	0	13.0	4	7	12	10	20	13	28	15
S Cancri	8	38.2	+19	24	8.2—10	9	11.6	1	21	11	8	20	19	30	7
RX Hydræ	9	00.8	— 7	52	9.1—10.5	2	6.8	4	10	11	6	24	22	31	18
S Velorum		29.4	—44	46	7.8— 9.3	5	22.4	3	6	9	4	21	0	26	23
Y Leonis	9	31.1	+26	41	9.3—11.2	1	16.5	4	13	11	7	24	19	31	13
RR Velorum	10	17.8	—41	36	10.0—10.9	1	20.5	4	18	12	4	19	14	27	0
SS Carinæ	10	54.2	—61	23	12.2—12.8	3	07.2	6	7	12	21	19	11	26	1
ST Urs. Maj.	11	22.4	+45	44	6.7— 7.2	8	19.2	9	10	18	5	27	0		
RW Urs. Maj.		35.4	+52	34	10.3—11.4	7	07.9	5	11	12	19	20	3	27	11
Z Draconis	11	39.8	+72	49	9.9—13.6	1	08.6	1	15	8	10	22	0	28	18
RZ Centauri	12	55.6	—64	05	8.5— 8.9	1	21.0	2	15	10	3	17	15	25	3
RS Can. Ven.	13	06.3	+36	28	7.5—12.5	4	19.1	6	1	15	15	25	5		
SS Centauri		07.2	—63	37	8.8—10.4	2	11.5	1	8	8	18	16	5	23	15
133926 Hydræ	13	39.0	—26	23	8.6—12.7	2	21.5	5	23	11	19	23	9	29	4
δ Libræ	14	55.6	— 8	07	4.8— 6.2	2	07.9	1	17	8	16	22	16	29	15
U Coronæ	15	14.1	+32	01	7.6— 8.7	3	10.9	2	17	9	14	23	10	30	8

Minima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1921 January					
	h m	° ′		d h	d h	d h	d h	d h	d h	d h
TW Draconis	15 32.4	+64 14	7.3— 8.9	2 19.3	5 7	13 17	22 3	30 13		
SS Librae	15 43.4	—15 14	9.3—11.5	0 18.4	3 21	11 13	19 5	26 20		
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	1 1	8 9	23 1	30 9		
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	5 3	13 9	21 15	29 21		
R Aræ	31.1	—56 48	6.8— 7.9	4 10.2	8 10	17 7	26 3			
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	8 12	19 13	29 6			
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	2 9	9 4	22 18	29 13		
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	1 10	9 19	18 5	26 14		
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	3 14	9 17	22 1	28 5		
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	1 12	7 16	20 1	26 5		
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	2 4	9 13	16 22	24 6		
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	2 1	10 5	18 9	26 13		
TX Scorpii	48.6	—34 13	7.5— 8.2	0 22.6	3 20	11 9	18 22	26 11		
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	6 21	14 15	22 9	30 2		
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	6 22	14 22	22 22	30 21		
WX Sagittarii	53.6	—17 24	9.2—10.8	2 03.1	9 0	17 12	26 0			
WY Sagittarii	17 54.9	—23 1	9.5—10.6	4 16.0	3 6	12 15	21 23	31 7		
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	4 15	15 0	25 8			
RS Sagittarii	11.0	—34 08	5.9— 6.3	2 10.0	5 9	12 14	19 20	27 3		
V Serpentis	11.1	—15 34	9.5—11.1	3 10.9	7 16	14 14	21 12	28 10		
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	6 2		21 5			
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	6 17	13 21	21 1	28 5		
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	1 2	8 5	22 10	29 13		
SX Sagittarii	39.7	—30 36	8.7— 9.8	2 01.8	2 2	10 9	18 17	28 0		
RR Draconis	40.8	+62 34	9.3—13	2 19.9	1 16	10 4	18 15	27 3		
RS Scuti	43.7	—10 21	9.3—10.3	0 15.9	2 9	8 0	22 7	28 23		
β Lyræ	46.4	+33 15	3.4— 4.1	12 21.8		12 18	25 15			
U Scuti	18 48.9	—12 44	9.1— 9.6	0 22.9	7 11	15 2	22 17	30 9		
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	3 12	11 2	18 16	26 5		
RV Lyræ	12.5	+32 15	11. —12.8	3 14.4	7 21	15 1	22 6	27 11		
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	2 15	11 14	20 13	29 12		
U Sagittæ	14.4	+19 26	6.5— 9.0	3 09.1	4 21	11 16	25 4	31 23		
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	2 2	9 11	24 4	31 13		
TT Lyræ	24.3	+41 30	9.4—11.6	5 05.8	5 19	11 1	21 12	26 18		
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	8 0	13 12	20 0	26 13		
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	3 8	9 8	21 8	27 9		
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	7 17	14 9	21 0	27 15		
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	3 16	12 19	21 22	31 2		
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	6 16	15 2	23 12	31 23		
RW Capric.	12.2	—17 59	8.8—10.6	3 09.4	6 12	13 7	20 2	26 21		
UW Cygni	19.6	+42 55	10.5—13	3 10.8	2 9	9 6	23 1	29 23		
V Vulpec.	32.3	+26 15	8.2— 9.8	37 19.0	6 13					
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	6 17	16 8	25 22			
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	5 7	14 12	23 17			
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	9 9	16 21	24 8	31 20		
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	7 15	14 29	22 20			
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	1 8	11 10	21 13	31 5		
VVCygni	21 02.3	+45 23	12.1—13.8	1 11.4	1 9	8 18	23 12	30 22		
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	2 7	11 23	21 16	31 8		
RY Aquarii	14.8	—11 14	8.8—10.4	1 23.2	1 2	8 22	16 19	24 16		
RT Lacertæ	21 57.4	+43 24	9.1—10.5	5 01.7	1 6	11 9	21 13	31 16		
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3	3 6					
RW Lacertæ	22 40.6	+49 08	10.2—11.2	5 04.4	6 10	11 14	21 23	27 4		
8.1914 Pegasi	51.7	+32 41	10 0—10.6	5 06.4	3 16	8 22	19 11	24 17		
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.4		8 17	16 23	25 7		
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	7 10	14 23	22 11	30 0		
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	3 13	11 19	20 12	28 7		

A New Star.—A Nova has been discovered by Miss Woods at R. A. $17^h\ 59^m\ 44^s$, Dec. $-31°\ 44'.9$ (1900). It was found by a comparison of a recent photograph with one made in 1914. The Nova appeared on the early plate. On a Bruce plate taken in 1902, no star is visible near this position brighter than magn. 17. On August 7, 1914, the Nova was fainter than magn. 11. On August 9, it was of about magn. 9.5, and on August 11 and 12 was at maximum, magn. 8. It began to fade at once and on October 8 had declined to magn. 12. On July 30, 1915, it was fainter than magn. 14. The position of this star, Nova Sagittarii, No. 7, is within a degree of that of Nova Sagittarii, No. 6, announced in H. B. 714.

S. I. Bailey.

Harvard College Observatory Bulletin 733.
Cambridge, Mass., U. S. A., November 13, 1920.

COMMUNICATIONS.

The Fallacy in the Laplacian Nebular Hypothesis.—A particle on the equator of a rotating and contracting body will not fly off or be left behind as contraction proceeds, but under Boyle's law of compressibility it will spiral inward at a uniform velocity. This may be demonstrated as follows:

Let a circle be surrounded by another circle of twice its diameter. The area of the large circle will be four times that of the small, and the area of the difference between the circles will be three times that of the small. But, under Boyle's law, the matter in the band surrounding the small circle will be only one and one-half times the matter in the small circle, because the matter in the small circle is twice as dense as the matter in the surrounding band. Only two-thirds of the matter in the band presses upon the matter in the small circle, the remaining one-third exerting lateral pressure; hence the matter in the small circle supports matter of the same quantity but one-half the density, and occupying therefore double the area. Now consider the body as rotating and contracting. Under Kepler's law the velocity of a particle on the shrinking equator should be accelerated as contraction proceeds, but such acceleration is checked because of *denser, slower-moving* underlying matter which impedes its progress. The equatorial particle imparts some of its momentum (the acceleration) to *two* slower-moving particles, where, if the density were the same, there would be but one. Hence, the particle will move only half as fast as it would but for such double density in the interior. Its velocity will remain constant. For illustration, assume that a particle on the equator of the large circle has been drawn by contraction into the circumference of the small circle. Suppose that while moving in the large circle it went 45° in a second. It would not go 180° in a second when it moved along the circumference of the small circle—it would go only 90°. Now the arc of 45° in the large circle is the same length as the arc of 90° in the small circle. The velocity of the particle would be the same in both circles. The particle would lose moment of momentum (required by Kepler's law) as it wound in. The shorter radius-vector would sweep in a second but half the area which the longer vector would sweep in the same time. The error which Laplace made, and which, so far as I know, has never been detected, is in assuming that this area must be the same after contraction as before. For it to be the same, the

equatorial particle must go 180° in a second, which, of course, would leave *its* moment of momentum unchanged. Equal areas would be swept in the same time by the expanded and contracted vector. But (what has been overlooked by everyone) acceleration has been prevented by the *double density* of the matter in the interior. Because of the contact under contraction between the rarer and denser parts, the velocity of the former is not accelerated, thus reducing the moment of momentum of the equatorial particle to one-half of what it was when it moved in the circumference of the large circle. But this loss is exactly made up by the momentum imparted to *two* underlying particles, *double* the mass of the impinging particle, just as, in translation, the velocity of a small rapidly moving body is retarded when it collides with a large slowly moving body. As in such case, the momentum of the whole remains unchanged, so in the case of rotation, the moment of momentum of the whole remains constant. The body contracts without change in the moment of momentum *of the whole*. Consequently, if at the start the centripetal is greater than the centrifugal force, it will remain greater, no matter to what size the body contracts.

It should be added that the moment of momentum of the matter in the excluded third part of the band surrounding the small circle will be conserved for the same reason that the moment of momentum of the rest of the matter is. The excluded part of the band may be cut up into an infinite number of parts of the same shape as the other parts. The sum of the moments of momentum of the particles in this space will remain constant under contraction. The denser parts at the bottoms of the ∇s composing the excluded area absorb the acceleration of the rarer upper parts as contraction proceeds.

It is strange that the foregoing has not been perceived, because the proposition that centrifugal will overtake centripetal force under contraction is self-evidently absurd. If this were so a body would contract and not contract at the same time. Centripetal force would cause contraction which centrifugal force, increasing at double the rate, would defeat.

Nov. 6, 1920. L. A. Redman.

GENERAL NOTES.

Dr. Daniel Buchanan, professor of astronomy and mathematics at Queen's University, has been appointed professor of mathematics and head of the department at the University of British Columbia. (*The American Mathematical Monthly*, November, 1920.)

M. Rajna.—Through a copy of the *Corriere D' Italia* of October 5, 1920, sent by Professor Pio L. Emanuelli, we learn of the death of M. Rajna, the director of the Observatory of Bologna. The science of astronomy has suffered severe losses recently, especially in Italy. There are now four Italian observatories without directors because of deaths. They are: Catania, Milan, Rome, and Bologna.

Astronomical Instruments returned to China.— It is of interest not only to astronomers but to every one to learn that the astronomical instruments, which were removed from Peking to Potsdam by Field-Marshal Count von Waldersee in 1901, have recently been returned to China. The following sen-

tence by Mr. A. C. Yate, Secretary of the Central Asian Society, in *The Observatory* for November, 1920, is authority for this: "My last Chinese paper reports that 20 huge cases had arrived in China by a Japanese steamer containing those astronomical instruments."

To Double-star Observers:—In accordance with the wishes of my friend, the late Professor Eric Doolittle, and my promise made to him in 1919, I have undertaken the completion of the Extension to Burnham's General Catalogue of Double Stars upon which he had been engaged since 1913 when Professor Burnham turned over to him the data he had collected. This arrangement has Professor Burnham's cordial approval.

The work should be published at the earliest practicable date and I have Director Campbell's assurance of such assistance on the part of the Lick Observatory as may be needed to complete the manuscript for the printer.

I respectfully request all double-star observers to co-operate by sending me copies of their papers printed in the present year as well as those which they publish later.

ROBERT G. AITKEN.

Mount Hamilton, California, November 5, 1920.

American Astronomical Society Meeting.—The twenty-fifth meeting of the Society will be held on December 28-30, 1920, at the University of Chicago in connection with the large quadrennial meeting of the American Association for the Advancement of Science. The Society has adopted the policy of meeting once in four years with the Association when a special effort is made to get all of the affiliated societies together at one of the centers, New York, Chicago, or Washington, taken in rotation. The last such occasion was when the Society met in New York in 1916.

The Society will meet in Room 32, Ryerson Hall, and there will be considerable opportunity to meet those from other societies, especialy at luncheon, which will be served at the University. As a convenience to those interested in special work, the astronomical papers will be printed in the general program, and it is proposed to prepare a list for each session, and those papers will be given in the order indicated. When the papers for any session have all been read, papers from a supplementary list may be called for. Arrangements are being made for a session at 2 P. M. on Wednesday, December 29, in connection with Section D (Astronomy) of the Association, and possibly with one or more other societies. The attention of members is called to the dinner of mathematicians and astronomers on Wednesday evening.

Clark Observatory.—We take pleasure in giving to our readers a brief description of The Clark Observatory located at 2205 W. Adams Street, Los Angeles, California. Our interest in this Observatory is increased at this time because we have just received gratuitously through Mr. Mars F. Baumgardt, Curator of the Observatory, an enlargement of a section of the moon, having dimensions 3 ft. 5 in. by 4 ft. 3 in. The scale of this picture is sufficient to show craters as small as one-fifth of a mile in diameter. The fact that a picture of this size should still be true to such small details is evidence both of skill in making the enlargement and of the fine character of the original negative. The enlargement was made by Mr. Baumgardt from a negative made with the

great 101-inch Hooker reflecting telescope of the Mt. Wilson Observatory. We consider this a distinct addition to our collection of pictures of celestial objects, and it has already been put to use in connection with the study of the moon.

A number of similar pictures of the moon of the size indicated and even larger are only a small part of the astronomical equipment of popular interest which Mr. Baumgardt has secured for the Observatory. There are, in addition to a six-inch refracting telescope, a room in which the appearance of the stars in the sky can very accurately be represented by rendering certain points luminous by radium; a room in which a large number of transparencies are illuminated by lights of various colors so as to represent approximately their natural color; a room in which stereoscopic views of the moon, comets, and meteors may be shown; a number of meteors, the largest of which weighs 357 pounds; models of all the planets made to a scale on which the sun is represented by a circle 41 feet in circumference; and many smaller items.

The Clark Observatory is private property on private grounds. However, cards of admission are freely granted, and the services of an instructor provided, to those who apply for the privilege. Such an unusual equipment must be a very entertaining as well as instructive feature for the people of Los Angeles and for the numerous visitors there.

The National Research Council.—A site for the new building in Washington which is to serve as a home for the National Academy of Sciences and the National Research Council has recently been obtained. It comprises the entire block bounded by B and C Streets and Twenty-first and Twenty-second Streets, Northwest, and it faces the Lincoln Memorial in Potomac Park. The Academy and Council have been enabled to secure this admirable site, costing about $200,000 through the generosity of the following friends and supporters: Thomas D. Jones, Harold F. McCormick, Julius Rosenwald, and Charles H. Swift, Chicago; Charles F. Brush, George W. Crile, John L. Severance, and Ambrose Swasey, Cleveland; Edward Dean Adams, Mrs. E. H. Harriman, and the Commonwealth Fund, New York City; George Eastman and Adolph Lomb, Rochester; E. A. Deeds, and Charles F. Kettering, Dayton; Henry Ford, Detroit; Arthur H. Fleming, Pasadena; A. W. Mellon, Pittsburgh; Pierre S. duPont, Wilmington; Raphael Pumpelly, Newport; Mr. and Mrs. H. E. Huntington, Los Angeles; Corning Glass Works, Corning, New York. Funds for the erection of the building have been provided by the Carnegie Corporation of New York.

The Gyroscope.—Under the auspices of the Department of Astronomy at Harvard University, Mr. Elmer A. Sperry, President of the Sperry Gyroscope Company of New York, gave a lecture on "The Gyroscope," on the evening of November 15, to a most enthusiastic audience at the Harvard Union. The principle and operation of the gyro-compass, ship stabilizer, and other devices developed for submarine and aircraft navigation were fully illustrated with gyroscopic apparatus, lantern slides, and motion pictures. The apparatus used by the lecturer became the property of the Astronomical Laboratory through the kindness of Mr. Sperry and the gifts of alumni interested in the Department.